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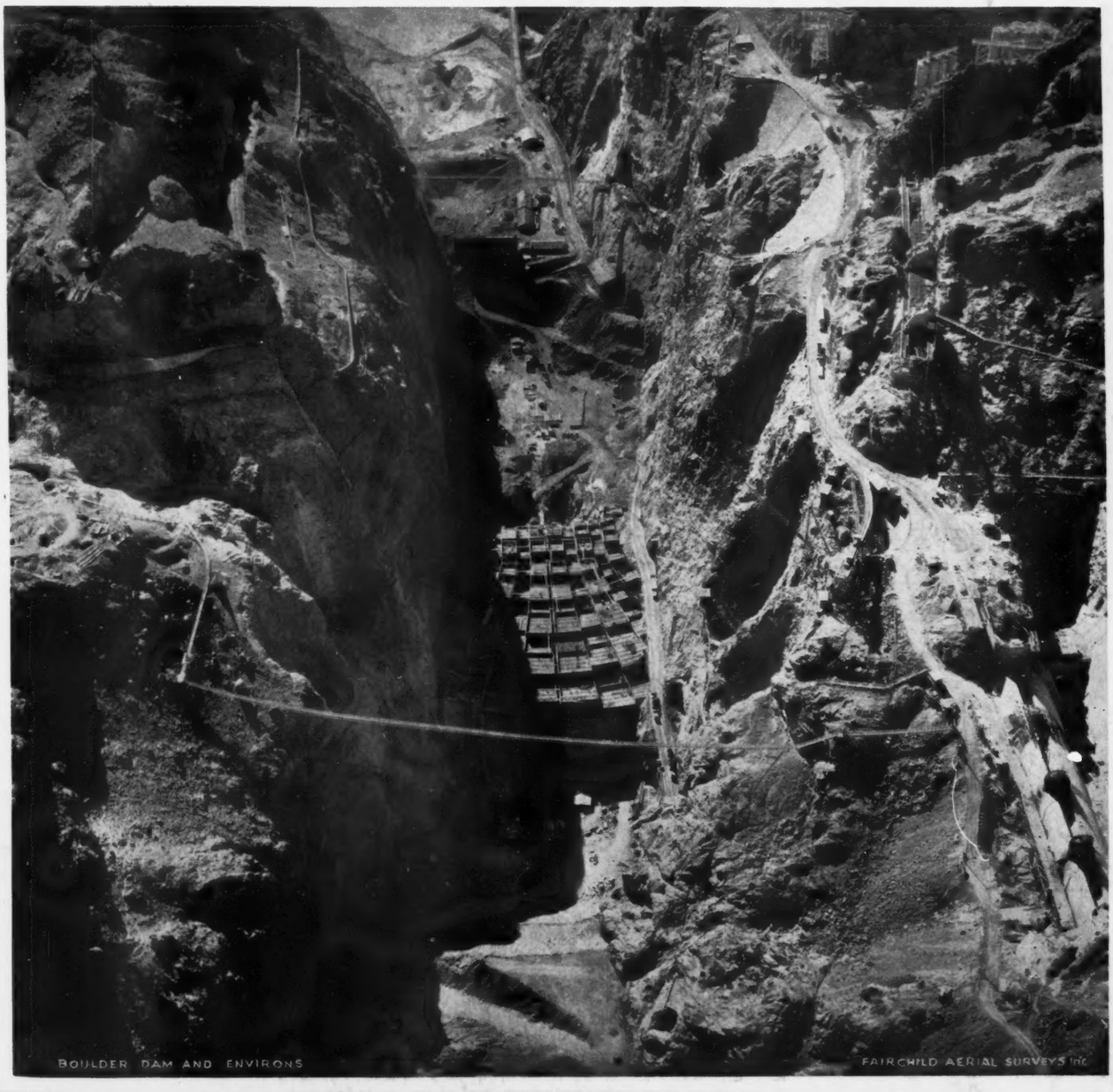
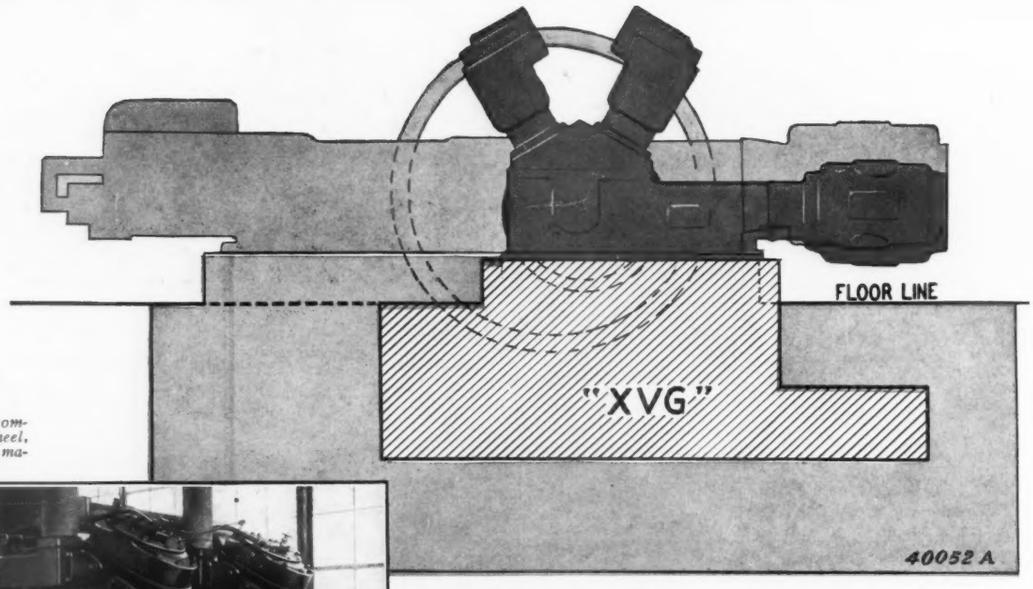
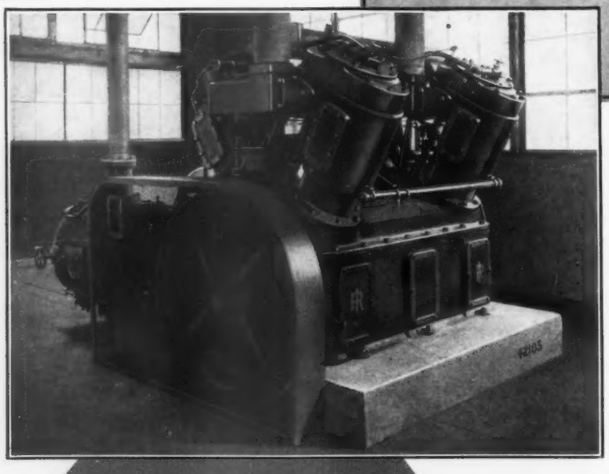




125 Hp. Type "XVG" compressor. Note small flywheel, which indicates a balanced machine.



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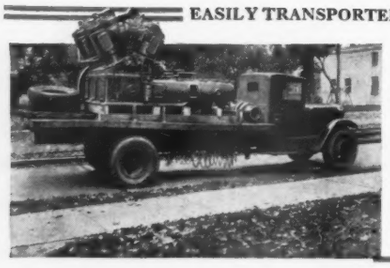

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As It Seems To Us

ECONOMY OF OIL ENGINES

ONE reason why the United States has more automobiles per capita than other countries is its lower cost of gasoline. Although we have burdened this fuel with taxes which yield a large share of our roadbuilding money, its price remains within the reach of more than 20,000,000 motorists. Even during the worst of the depression, Americans demonstrated that they were not yet ready to accept the diminutive cars Europeans have adopted to counteract high gasoline costs.

At the same time we have not turned our backs on improvements in engine design that might reduce the fuel bill; and we are now at the interesting point where it appears that the sovereignty of the gasoline engine will soon be challenged. For many years we have been building and using large engines that burn fuel oil. Diesel-engined ships now sail the Seven Seas; and the diesel likewise serves widely on land for driving generators, locomotives, and other heavy-duty machines.

During recent years the trend has been to apply the oil engine to lighter tasks, and it has found increasing application in such machines as power shovels, tractors, and portable compressors. An article in this issue describes the experience of a western contracting firm with a portable compressor driven by an engine that has been adapted to burn a wide range of readily procurable fuel oils by combining spark-plug ignition with the solid-injection principle. The full import of its economy is apparent if we consider that it produces compressed air at a fuel cost of around 1½ cents per 1,000 cubic feet.

The success of the fuel-oil engine in the industrial field appears to presage its adoption for automotive vehicles. Engines of this new type already have been tested with good results in trucks. A British-made truck, weighing 6¼ tons and carrying a pay load of 8½ tons, recently made a run in Australia at a fuel consumption of only one gallon per ten miles.

There are numerous examples of this trend in the United States. An oil-engined truck in regular service between Los Angeles and Seattle is reported to make the 2,000-mile round trip at a fuel cost that is $100 less than it would be if gasoline were used. The fuel oil costs 5½ cents a gallon, and one filling of the tank suffices for a 1-way trip. A Los Angeles man who equipped a Ford Model A pleasure car with a fuel-oil engine claims to have traveled 25,000 miles at a fuel cost of $29. One of the largest bus operators in the country has had two diesel-electric buses running for more than two years in order to compare their operating costs and performances with those of conventional types of vehicles. Results of the test have not been made public.

OUR COVER PICTURE

CLOSE inspection of this aerial view in connection with the reading of the first article in this issue will give a clear idea of the extensive facilities that have been set up for pouring Boulder Dam. The area pictured is about one-half mile square.

AN INTERNATIONAL HIGHWAY

A CONTINUOUS road stretching from Canada southward through twelve countries to the tip of South America, wide enough and level enough for safe and easy driving, and routed through the most colorful sections of the areas crossed—such is the plan that is now taking shape. Who could visualize a better way to cement amicable relations between the various nations of the two Americas; to promote the interchange of ideas; to stimulate trade; in short, to get better acquainted? With all these worthy objects in view, and with the further incentive of putting men to work, the project seems assured of success. It speaks well for the friendly international feeling that pervades all the countries concerned that a scheme of this sort could receive favorable consideration in unsettled times such as these.

Mexico is hard at work finishing her link in this vast Pan-American chain of communication, and before the current year is over it will be possible to drive comfortably from Canada to Acapulco, on the Pacific Coast, 1,000 miles south of Laredo, Tex. This road represents the fruit of seeds sown in 1925 by President Calles. It is one of four great arterial highways converging upon Mexico City. Heretofore only hardy and experienced motorists would attempt the journey from Laredo to Mexico City. In many places the way was narrow, steep, and dangerous. By October, however, the 783-mile stretch will be a 2-lane modern highway. The transformation is being wrought by Salvador Toscano, Mexico's greatest road engineer. A stickler for 6 per cent maximum grades, he has used drill steel and dynamite effectively to bend the rugged topography to his will. Where the route traverses the Sierra Madres Mountains, more than 3,000 men were employed on its construction.

The road has been located with an eye to scenic attractions as well as to directness; and Mexico is already anticipating an influx of American tourists. Bureaus have been established to distribute descriptive literature and to stimulate travel interest.

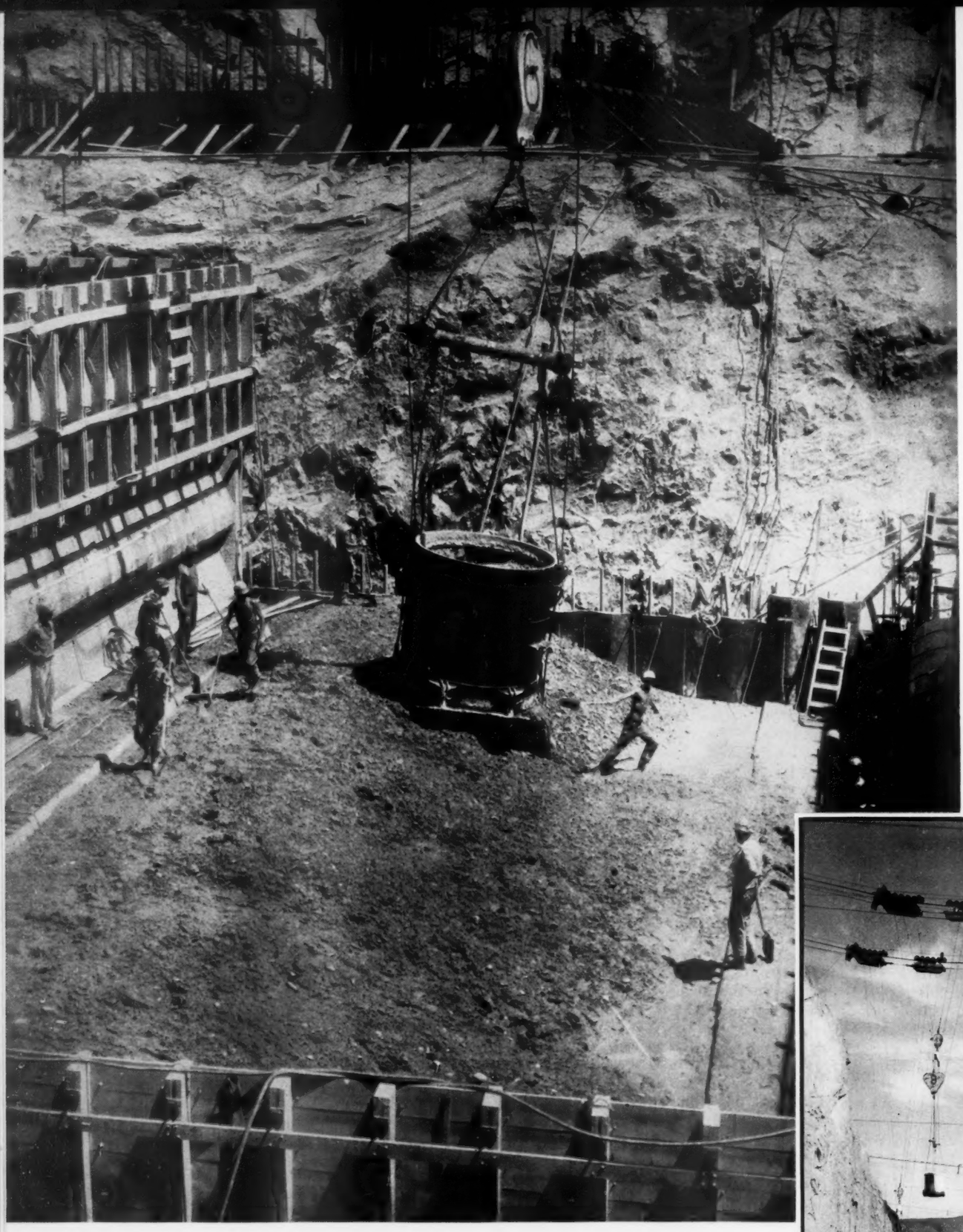
GOLD FROM THE SEA

REAL romance attaches to the account given before the American Chemical Society of the means by which the Ethyl-Dow Chemical Company is recovering bromine from sea water near Wilmington, N. C. Not the least alluring phase of it is the prediction by scientists of high standing that the old dream of taking gold from the ocean bids fair to be realized before very long. Just how near that time may be is not yet predictable; but of significant bearing upon it is the declaration that the problem presented is no more difficult now than was the problem of extracting bromine ten years ago.

The aggregate amount of gold in the sea is so great that the reputed wealth of King Midas pales into inconspicuousness by comparison. The existence of this fabulously rich store has been known for many years, but a different aspect is placed on its value if one assays a sample of the "ore," so to speak. The gold is so sparsely distributed that something like 13,020 tons of water would have to be treated to yield one troy ounce of the metal on a basis of 100 per cent extraction. That this could be done profitably appears ridiculous until we consider that the largest item of expense involved, namely, pumping, can now be charged to the recovery of bromine, as that industry is on a paying basis. However, for every ounce of gold obtained we should be adding 30,000 ounces of bromine to the world supply, and it requires no expert economist to deduce what would soon happen to the price of bromine. But it is possible that additional valuable constituents of the water could be reclaimed, and that their combined worth would be sufficient to defray the cost and leave a goodly part of the gold as profit. There is, for instance, about 1,000 times more silver than gold in the sea, and it is likely that this mineral could be extracted at relatively little additional cost.

Gold occurs in colloidal form in the ocean, but it is believed that its conversion into a state in which it would be readily recoverable would be a comparatively simple phase of the entire problem. In spite of the apparently long odds against its achievement, it would be an extremely foolish person who, aware of some of the miraculous feats of modern science, would ridicule the idea that some day man will wrench the sea's gold hoard from its grasp.

Meanwhile, it is perhaps just as well that Father Neptune clings to his treasure so tenaciously. If some one were suddenly to find means for profitably recovering it, the consequences to the world economic system might be startling. Imagine adding 1,500,000,000,000 ounces of gold to the existing supply! Yet this is the estimated content of the sea, as computed from the Physical Tables of the Smithsonian Institution.



SIXTEEN TONS OF CONCRETE

THE bucket shown above, containing 8 cubic yards of concrete, is being landed in one of the forms. The men closest to it on either side have tripped the safety latches on its bottom-dump doors and are getting into the clear as the cableway operator, more than 600 feet above them, releases the concrete upon signal from a man at the form. The form is 5 feet deep and about 50x60 feet on the sides. Its left side is being filled first, creating a sloping surface towards the right. This procedure is followed during hot weather to keep the surface of the concrete "live". At other times the form is filled progressively throughout. On the right a cableway is moving off with a bucket of concrete just taken from a car on the high-level railroad.

All photographs not otherwise credited are from Six Companies Inc.

Construction of the Boulder Dam*

Description of the Methods of Pouring the Concrete

LAWRENCE P. SOWLES†

PLACING CONCRETE BY CABLEWAY SYSTEM

This view, looking upstream at the dam from the lower catwalk across the canyon, is interesting because it shows the relationship between the pouring area and the overhead cableway system. In the upper part of the picture are shown the carriages of all five cableways. Suspended from them by fall lines are 8-cubic-yard buckets of concrete. The concrete delivery railroad from the Lomix plant is seen along the edge of the Nevada canyon wall at the left. The structure across the canyon in the middle of the picture is a catwalk for workmen. For a plan drawing of the cableway system see page 4391.

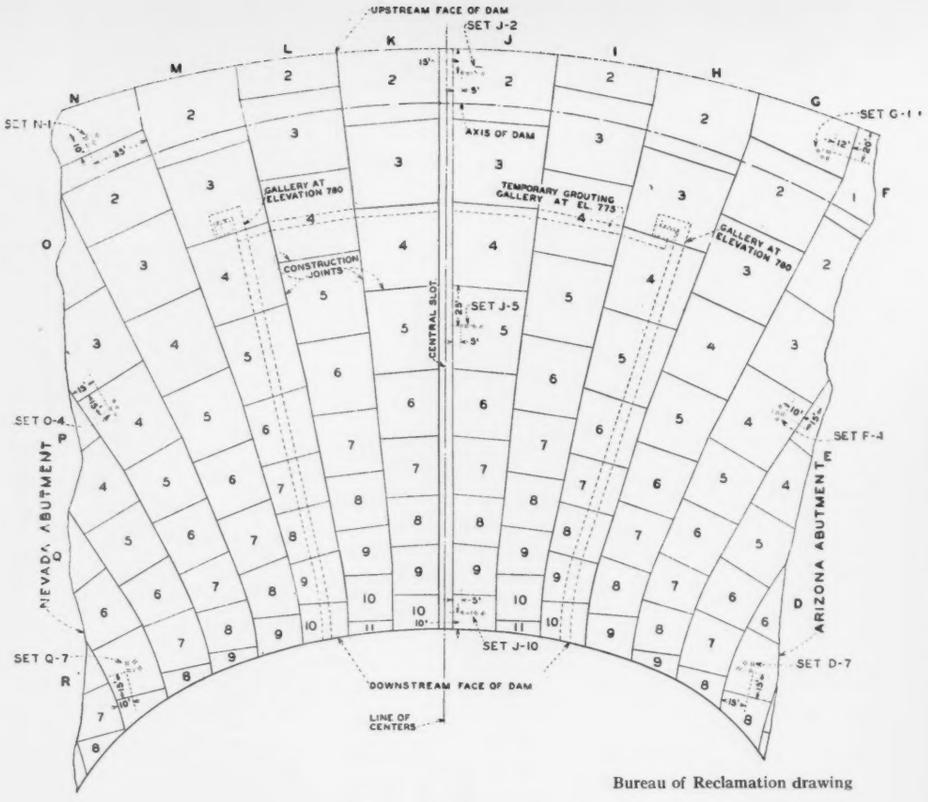
THE construction of Boulder Dam is primarily interesting because of the enormity of the work involved. The building of a big concrete dam consists essentially of placing a large volume of concrete in one mass in accordance with a specific design, and of providing the necessary appurtenances and accessories. Except for their scale of application, the operations in the case of Boulder Dam are much the same as those that have been performed in rearing many other dams of more or less consequence.

Owing to the unprecedented size of this particular structure, unusual specifications and stipulations for controlling the work were set down by the U. S. Bureau of Reclamation to insure an enduring and safe dam. To satisfy these restrictions and to handle the immense quantities of concrete involved at a rate never before attained, Six Companies Inc. have organized their forces and equipment to bring about a concentration of activities that stamps this undertaking as unique among all similar ones that have gone before it. It is not easy to grasp what it means to mix, transport, and place 3,220,000 cubic yards of concrete in a tapering mass 727 feet high; to deposit it in several hundred individual columns in conformance with rigid rules; to provide, the while, for galleries, drainage structures, and grouting and cooling pipes; to do all these things in an orderly, painstaking manner; and to maintain a schedule that will assure the completion of this phase of the job within the next two years. Perhaps it will help us to comprehend the huge scope of the activities if we state that 25 carloads of cement and approximately 150 carloads of aggregates are required to make up the concrete that is placed every average day.

The design of the dam is based upon researches which have been carried on almost since the Bureau of Reclamation was created in 1902, and upon the accumulated experience obtained in building more than 50 concrete dams during that period. Incidentally, Boulder Dam will contain more concrete than the preceding 50, a circumstance that warranted special intensive study to determine beforehand how concrete would behave when poured in a mass of this size and height, and to make it possible to specify materials, methods, and

†Engineering Department, Six Companies Inc.

*Seventeenth of a series of articles on the Colorado River and the building of the Boulder (formerly Hoover) Dam.



Bureau of Reclamation drawing

PATTERN OF THE DAM

Boulder Dam is being built of regimented columns lettered as to rows and numbered as to their positions. Owing to the taper of the mass from bottom to top and the variable width of the canyon, the pattern of the dam is an ever-changing design. At the left is a plan of the columns as they are disposed at elevation 800, a little below mid-height of the structure. The notations around the edges, such as "Set O-4," refer to the locations of strain meters to be embedded in the concrete. Below is shown the dam as it actually appears at elevation approximately 800.

practices that would serve to best advantage.

Space will not permit going into the details of the many and interesting tests that were conducted, or to show how they influenced the plans and specifications. These matters were summed up recently in a published statement by B. W. Steele, engineer on design of dams for the bureau. Mr. Steele stated that it has been the aim of the designers to produce a mass concrete of greater durability and higher quality than heretofore placed by the bureau, and that this purpose guided them in preparing specifications for the concrete plants, for the mix for the mass concrete, for the blended low-heat cement of a controlled composition, for bottom-dump concrete buckets, and in making provisions relative to the placement and curing of mass concrete. Thus far, the experience in connection with the actual construction of the dam indicates that these efforts have been entirely successful and have led to the following conclusions: That the structural qualities and the graduation of the aggregates are the best ever obtained in a dam built by the Bureau of Reclamation; that the contractors' plant for the production of concrete is probably superior to any ever used on similar work; that the strength of the concrete as poured is ample for any stress condition that may result in the dam; that a water-cement ratio of 0.53, using one barrel of cement to each yard of concrete with a slump of 3 inches at the forms, makes for a more uniform concrete than can be obtained with a lower slump under the conditions encountered on the job; that uniformity is the most important factor in the entire concrete-manufacturing process; and that all specifications covering concrete must be considered with regard to their effect on uniformity.

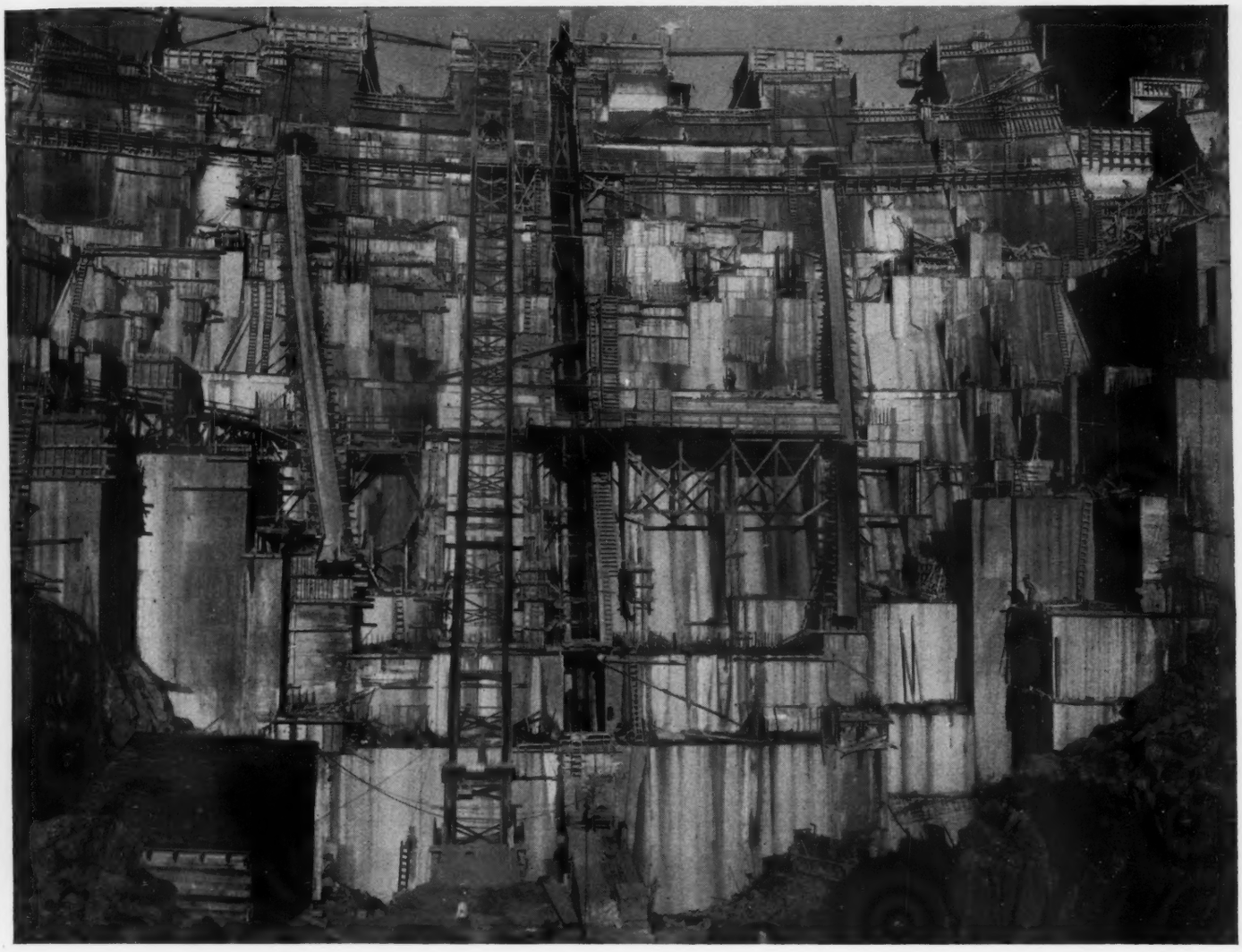
Concrete entering into the dam is produced at two locations: at Lomix, which is situated on a bench on the Nevada side of the canyon bottom and about 4,000 feet upstream from the dam site, and at Himix, which occupies a site on top of the Nevada rim of the canyon. In either case, the concrete is moved from the mixing plants in 8-cubic-yard bottom-dump buckets placed on railroad cars; is spotted in position underneath any one of the five cableways that span the canyon; and is conveyed from the cars to the forms by cableway. A minor variation in this general procedure will be described later.

The railroad which delivers concrete from the Lomix plant to the dam runs at elevation 720, and all the concrete placed in the dam up to this level came from that plant. Pouring is now in progress at elevations above 720, and from there on to elevation 975 concrete will be furnished from both plants. When elevation 975 or thereabouts is reached, the Lomix plant will, it is contemplated, cease to operate. From elevation 975 to the crest, at elevation 1232, concrete will be supplied from the Himix plant exclusively. For the time being we shall confine ourselves to an account of the methods followed in placing concrete produced at Lomix and in that portion of the dam below elevation 720.

The railroad from the Lomix plant to the dam site is a part of the line designated as the Canyon Railroad. It was used extensively during the early building period for removing muck from excavation areas. It is of standard-gauge, double-track construction, and hauling over it was done with steam locomotives until concrete transporting began, when the section from Lomix to the dam site was converted to electric operation. Third rails were provided except at the mixing plant, at the downstream terminus where the buckets of concrete were handled by cableway, and at switches. They were omitted at those points to avoid the possibility of men or water coming in contact with them.

The locomotives are of the storage-battery type—the batteries furnishing the required operating power where there is no third rail and being charged from the third rail at a rate that makes it unnecessary to remove the units from service for recharging. The third rails are supplied with 320-volt direct current by two generators located midway of their length. The locomotives originally were of 36-inch gauge and used for hauling muck in the 12x12 top headings of the diversion tunnels. They were converted to standard gauge and were equipped with air brakes, air compressors, and third-rail shoes in the machine shops of Six Companies Inc.

For concrete haulage, a special car was built on a standard flat-car bed. A back wall and five lateral partition walls were installed, thereby creating four wells each approximately 10 feet across and designed to accommodate a concrete bucket. The side of the car towards the dam was left open to facilitate the landing and removal of the buckets. The tops of the back wall and partitions were made wide enough to provide walkways for the men who hook and unhook buckets at the cableway



LOOKING THE DAM IN THE FACE

The downstream face of the dam as it appeared on January 24, 1934. The irregularity of the lower blocks is occasioned by the fact that they will be used as footings for the power house which will occupy this space. The cooling-pipe slot with the headers rising in it is shown in the center. The vertical structure just to the left of the slot is an elevator which provides access to and from the top of the dam. This picture gives a fair idea of the immense amount of incidental structural work that is required in connection with the placing of the concrete. During the pouring of the concrete, the labor force on the dam has reached the highest number employed since the work began.

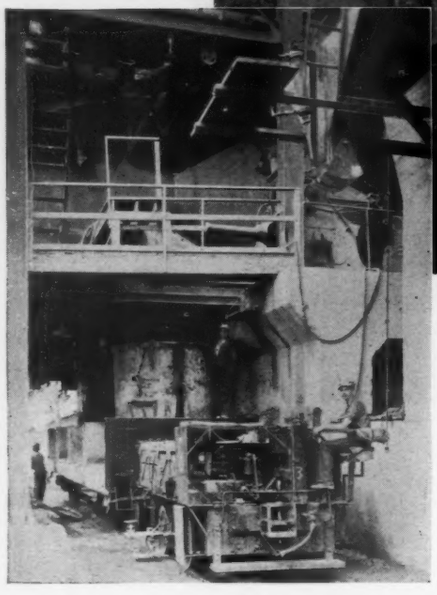
loading points. The spacing of the wells was a little more than half that of the four mixers at the Lomix plant. When loading, a car was spotted so that two buckets, in alternate wells, received half of their 8-cubic-yard charge from the first and second mixers in the line of four, and was then moved alongside mixers Nos. 3 and 4 from which they received the second half of their charge.

Each concrete train consisted of a locomotive and one car with two loaded buckets in alternate wells, as just described. Upon arriving at the terminus adjacent to the dam, the car was spotted so that one of the two empty wells was directly underneath the hook of a cableway bearing an empty bucket. This was then landed on the car. While the hookers were disengaging the slings from the rim of the bucket, the train moved on until the adjacent loaded bucket was directly beneath the cableway falls, so that it could be hooked on to the slings and hoisted and carried by the cableway to the block in the dam in which it was to be poured. The train then proceeded to a point where another empty was waiting suspended from a cableway. There the same procedure was repeated—the train moving back to Lomix with its two empty buckets properly spaced to correspond with the mixers.

The section of the railroad at the downstream or dam end was one of the most interesting and expensive stretches ever built in this country. The original terminus consisted of a timber trestle, 100 feet high in places and 160 feet long, that carried the tracks almost up to the dam site. As then constituted, the railroad was used for hauling supplies into the canyon construction zone and for disposing of much of the muck that came from the upstream portals of the diversion tunnels. Its extension within the dam lines had to await the completion of scaling operations on the Nevada canyon wall, which was to serve as the dam abutment on that side. Actually it was not extended until just prior to the beginning of concrete pouring in the dam area. Within the dam lines the construction consisted of steel bents and floor beams with timber stringers, ties, and flooring. Steel was used for the under supports because, as concreting progressed upward, these members had to be cast within the mass of the dam.

As the canyon wall beneath the trestle was practically vertical, extremely long trestle legs were required to support its overhanging edge, even though heavy cuts were made into the rock on the canyon-wall side to reduce this overhang. To facilitate the placing of concrete underneath the trestle, the bents were made as simple as possible. Instead of the usual longitudinal braces, the bents were tied together and made rigid by means of flooring laid diagonally both ways on top of the ties in the space between the rails. As the elevation of the concrete neared that of the top of the bents, the stringers were removed and another method of handling the concrete was adopted. This will be described later.

Upon reaching the trestle section, the con-



DELIVERING CONCRETE FROM LOMIX

A double-track railroad, clinging to the sheer wall of the canyon with the support of long steel trestle legs, made it possible to deliver concrete for the lower section of the dam directly alongside of it. The 8-cubic-yard buckets, two to a car, were hauled from the Lomix plant by electric locomotives. As soon as a car was spotted at the dam site, a cableway deposited an empty bucket in one of the four wells and then picked up a full one for transportation to the forms. Repetition of this procedure disposed of the load and enabled the train to return to the mixing plant. In the view above, an empty bucket is being landed on the farthest car and a full one is being moved for pouring in a form near the lower left corner of the blocks. The second picture shows a concrete car being loaded at the Lomix plant. The buckets are spaced so that each is directly under the discharge of a 4-cubic-yard mixer.

Bureau of Reclamation photo

crete trains came under the control of a dispatcher who directed all their movements to and from the cableway spotting location. By means of a bank of levers in front of him, he maneuvered all switches leading to the trestle and for the crossovers on the trestle. The actual opening and closing of the switches were done with pistons actuated by compressed air. This system proved efficient in preventing tie-ups at one of the bottleneck points in the line.

The cableway system by which the concrete is placed in the dam was described in our April, 1933, issue. The method of handling the buckets with these aerial transportation agencies is one of the intensely interesting and spectacular features of the work at the dam. The difficulties attending the correct handling, landing, and spotting of a loaded bucket during the pouring of the lower part of the dam can be comprehended when it is realized that it constituted a weight of approximately 20 tons dangling at the lower end of 650-foot fall lines extending down from two carriages riding upon the track cable overhead.

For each cableway there was a signalman at the loading point and another at the pouring point. Both were connected by the same telephone circuit with the cableway operator in the head tower on the Nevada rim of the canyon far above them and out of their sight. Thus, they were able to give signals orally, as well as by the conventional system of bells and lights. By joint effort, these two signalmen had to direct the movements of the buckets between the delivery trains and the forms. Each loaded bucket had to be spotted precisely at the desired point for pouring and, when empty, had to be piloted unerringly back to its particular well on the car. These maneuvers involved not only cross-canyon movements but also longitudinal shiftings. The latter were guided solely by the signalman on the forms, his directions causing the cableway operator to propel the towers upstream or downstream on their runways, as need be. All other movements were under the joint control of the signalmen. Where one relinquished command, the other took it up.

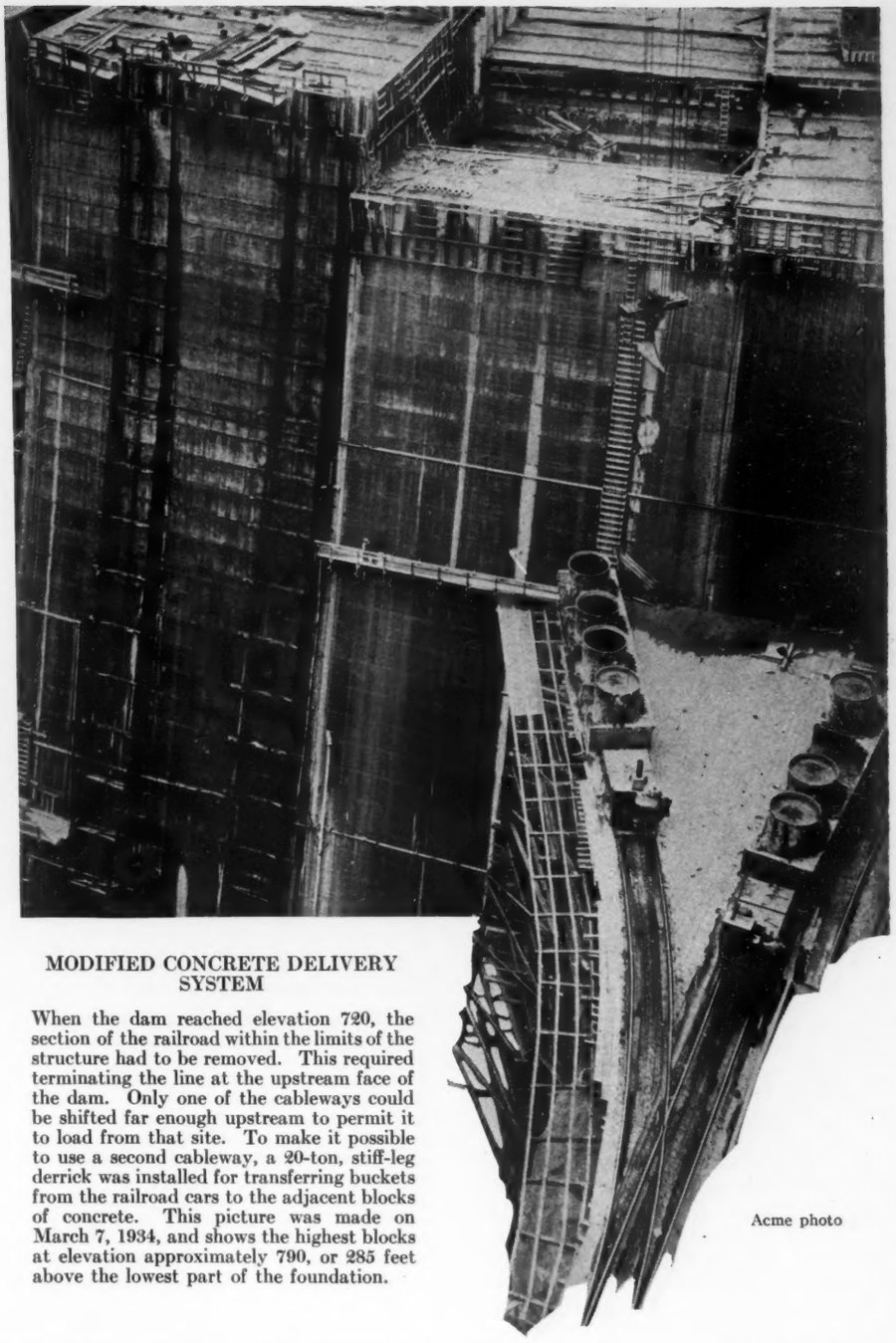
It required no mean skill, alertness, and coordination for the signalmen to determine the exact point and time at which to stop the carriage on the track cable an eighth of a mile above so that the bucket might complete its swing immediately over the particular area in the block for which the concrete was destined and then, while the bucket was momentarily stationary at the end of its swing, to bring the carriages promptly into position directly above that point so as to catch and stop the pendulum action of the bucket and to prevent any back swing. This accomplished, the bucket would be lowered to the surface of the block where two men of the placing crew released the safety latches on the bottom of the bucket with their shovels. Meanwhile they guided

the load to the spot where they wished the concrete poured, and then scurried into the clear as the signalman flashed word to the cableway operator to dump the 16-ton charge.

As soon as a bucket was empty, it was closed and hoisted to the required height for landing on the car on the trestle. The carriages overhead were next pulled toward the canyon wall, and after a lapse of several seconds, during which they had traveled as much as several hundred feet, the bucket began to swing and to attain its full velocity. Here again it was necessary for the signalman to gauge just how far to move the carriages so that the pendulum motion of the bucket would carry it to the exact point above the car on which it was to be landed, and then, while it was momentarily at rest, to bring the carriages quickly and directly above the bucket and to stop them there while the hook tender on the car assisted in the final spotting over the designated well.

Let it be said to the credit of the signalmen that there were but few times when the buckets were banged against the rock wall behind the loading point on the trestle, while there were thousands of instances when the buckets were landed neatly and smoothly on the cars. It was, indeed, fascinating to watch bucket after bucket come gliding up to the landing point, slide into a well on the car and be lowered into place—all with practically one motion which represented the ultimate in concerted action and timing. Especially careful were the signalmen in spotting buckets at the pour points on the columns to prevent them from hitting men or forms, which latter contingency might have proved extremely disastrous to all workmen in the vicinity.

As previously stated, concrete was delivered right from the Lomix plant to cableway loading points by the Canyon Railroad during the pouring of all that part of the dam from the lowermost point (elevation approximately 525) to the railroad level at elevation 720. Since the space occupied by that section of the railroad lying within the dam lines was itself to become filled with concrete, its use obviously had to end when pouring reached elevation 720. However, there were certain economies to be gained by continuing production of concrete at Lomix, and, accordingly, when the system was changed, this was provided for. Cableway 5 was still in a vertical plane with that portion of the 720 trestle immediately upstream from the dam, and was therefore able to load directly from the cars and to place the concrete by the traveling towers as required. To make it possible also to utilize Cableway 6, a 20-ton, 140-foot-boom stiff-leg derrick was installed in such a position as to enable it to transfer buckets from the cars on this trestle to adjacent points on the dam, from which the cableway picked them up. Cableways 7 and 8 were based on the Himix plant for their source of supply, receiving the buckets from cars on the high-level railroad, at elevation 1235, and lowering them to the working level on the dam. As they were more heavily loaded on the downward trip than on the return, their lowering speed was increased by reeving these cableways 3-part. This arrangement will suffice as long as it is economically practicable to continue the Lomix plant in production. After that, all the concrete will be supplied by the Himix plant.



MODIFIED CONCRETE DELIVERY SYSTEM

When the dam reached elevation 720, the section of the railroad within the limits of the structure had to be removed. This required terminating the line at the upstream face of the dam. Only one of the cableways could be shifted far enough upstream to permit it to load from that site. To make it possible to use a second cableway, a 20-ton, stiff-leg derrick was installed for transferring buckets from the railroad cars to the adjacent blocks of concrete. This picture was made on March 7, 1934, and shows the highest blocks at elevation approximately 790, or 285 feet above the lowest part of the foundation.

Acme photo

After the dam reached elevation 720, the full capacity of the Lomix plant was no longer required, so one mixer and one set of batchers were removed and reinstalled in the Himix plant. The three mixers then remaining at Lomix were arranged for feeding from one line of batchers. Before the Himix plant came into use for supplying dam concrete, it had been furnishing material for spillway structures and for penstock-tunnel linings. It had four mixers served by three lines of batchers. The additional equipment from Lomix gave it five mixers and four lines of batchers.

Eight-cubic-yard buckets were selected because they facilitated meeting the specifications which prohibited continuous pouring at the dam and stipulated that "a mixer batch, or combination of mixer batches, shall be conveyed in one mass to its location in the dam." The buckets are of welded-steel construction, cylindrical in shape, approximately 6 feet 10 inches in diameter, and 7 feet deep. Each is suspended from the cableway hoist and dump blocks by two sets of slings—one set being made fast to the shell of the bucket by sockets and removable pins and the other set being made fast by sockets and removable pins to the I-bars supporting the bottom-dump doors of the bucket. The possibility of accidentally dumping a bucket in mid-air is eliminated by safety latches on lugs at the points of the doors.

As previously mentioned, buckets of this type are generally used for pouring. However, where the dam abuts against the canyon wall, or where a block becomes very narrow because

WHERE THE DAM WILL REST

Excavation of the river bed revealed conditions there essentially as indicated by preliminary exploratory drilling. Bedrock on either side was struck at elevation approximately 600, but in the center there was an inner gorge that had been scoured to a further depth of 80 feet. This view shows pouring of the first block of the dam on June 6, 1933. The wagon drill in the center foreground was being used to drill grout holes, some of which were being filled by the pump mounted on the truck at the right. In the distance is the skeleton of the water cooling tower that now serves in connection with the cooling of the concrete after it is poured. The structure along the canyon wall at the right is the railroad, at elevation 720, over which concrete for the lower section of the dam was delivered.

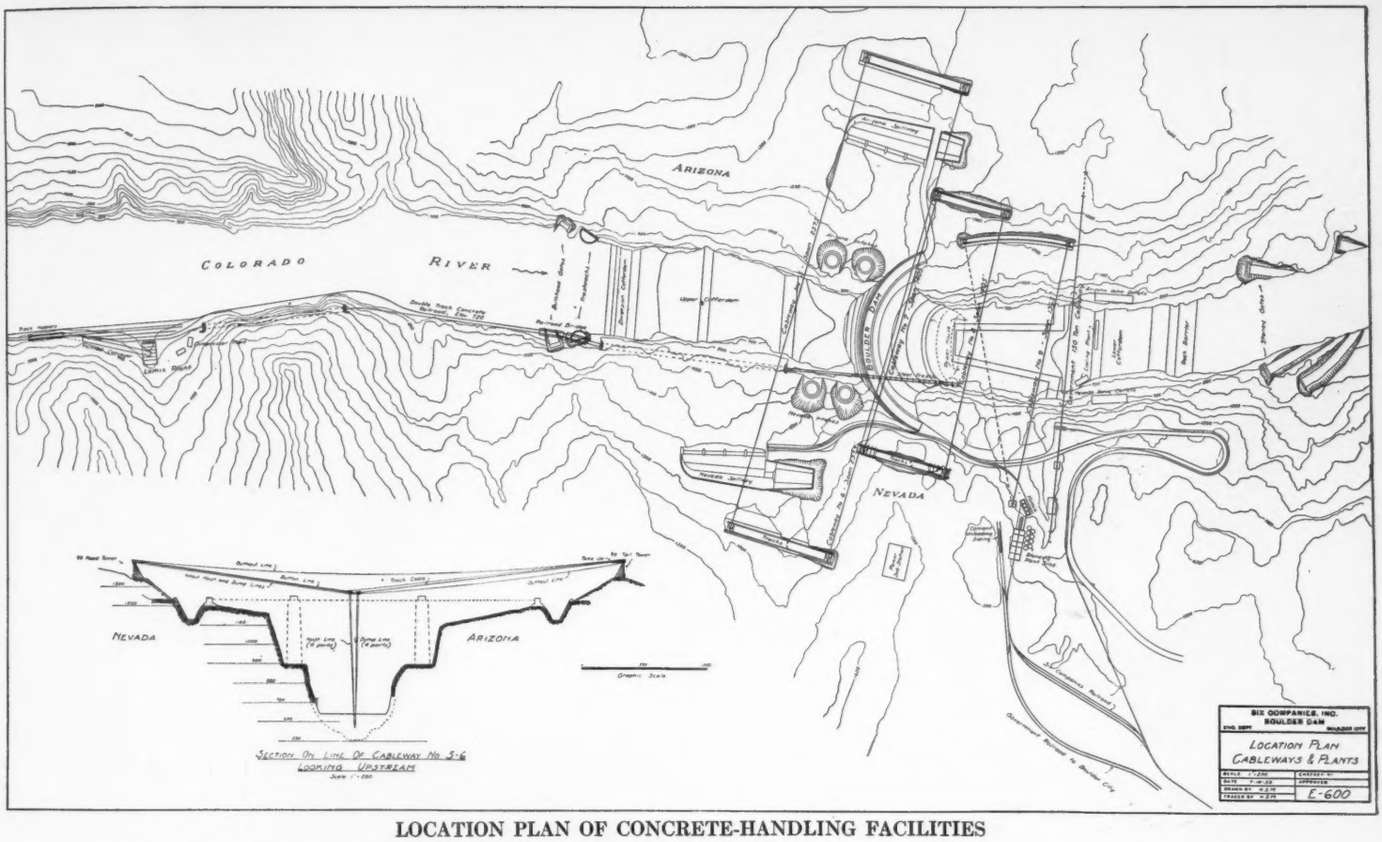
of the backward slope at the dam face, the width of a form is sometimes not great enough to admit a bucket of such size. These fractional pours, as they are known, were at first made by lowering the concrete in 4-cubic-yard agitators. Later on, an 8-cubic-yard bucket, having a hand-controlled radial gate, was developed for this purpose and is now being employed.

The working of the concrete into the forms after it has been deposited is done mainly by men in rubber boots who walk around in the mass, spreading it into place along the edges to insure neat form finishes, and tamping it around pipes, galleries, and such other structures as have to be cast in the dam. As originally specified, the concrete was to be deposited in 1-foot layers extending over the entire form area. A trial of this method disclosed that it was impossible to maintain a "live" working surface during hot weather because the concrete dried too rapidly. It was, accordingly, decided to modify the procedure when weather conditions necessitated it by starting the pour at the downstream edge of each block, building up that side to the top of the form, and keeping the working face inclined toward the upstream edge of the dam—subsequent pours on the low side then progressively filling the form. This method is proving satisfactory, and keeps the working face "live" in even the largest blocks. During the winter months the procedure originally outlined is used. Vibrators are generally resorted to only where it is difficult to work the concrete by hand, as around embedded structures. A placing crew consists of seven men and a foreman in the larger blocks, and of five men and a foreman in the smaller ones.

A number of related operations must be carried on simultaneously with the placing of the concrete, and these must be timed and coordinated so as not to delay the pouring schedule. Among these are: placing drain tiles, grout stops, cooling pipes, gallery forms, grout pipes for contraction joints, thermometers, strain meters, and other instruments, as well as raising and checking forms. Pouring in each form is done in 5-foot lifts. As soon as a lift has set to a certain degree, a crew enters the form to clean up the surface of the concrete. This is done by scouring it with a jet of compressed air and high-pressure water, a method that produces a fine stream of water particles traveling at a high velocity and having an effect similar to that of a sand blast. This treatment removes any scum or laitance which may have formed, leaving a roughened surface with the aggregates exposed and insuring a good bond with the next pour of concrete. The water also serves to carry off the undesirable material and to convey it to a drain hole in the lowest block in the area.

Forms are generally left in place for about 24 hours after a pour. They are then stripped off, raised, and reset above in preparation for the next pour. When in position, they are checked for grade and line by Government engineers, who provide any additional points required to set them with the accuracy demanded by the specifications. The forms are hoisted by means of small A-frames on each of which is mounted a hand winch. Ordinarily, two frames are used for each panel, but three are needed to raise the longer ones, which have an extreme length of 61 feet.

The forms consist of wood panels lined with sheet metal, and are held in position by shebolts, tie-rods, and braces which are attached to small hook bolts, called pigtails, embedded in the concrete. These hook bolts are placed



LOCATION PLAN OF CONCRETE-HANDLING FACILITIES

All concrete poured in the dam from the lowest point at elevation 505 up to elevation 720 was produced at Lomix, shown near the left edge. The mixers discharged into 8-cubic-yard buckets placed on flat cars, and these were then hauled to the dam site, 4,000 feet downstream, where they were picked up by one of the five 20-ton aerial cableways that span the canyon high above and transported to pouring areas. Between elevations 720 and 975 the dam is being built with concrete from both the Lomix and Himix plants. The latter is located on the Nevada rim of the canyon, and from it a railroad runs at elevation 1235 underneath the five cableways. While the lower portion of the dam was being poured, the Himix plant was furnishing concrete for the spillways and intake towers on either side of the dam and for the lining of the penstock tunnels and other structures. It will be noted that the cableways, by means of their traveling towers, can deliver concrete to every section of the dam, power house, and appurtenant works. The Government 150-ton cableway, which appears as a straight line at the right of the contractors' cableway system, is being used for handling steel pipe for lining the penstock tunnels. Later it will also be utilized for lowering the generating equipment into the power house.

in the top of each lift, at intervals of approximately 2½ feet, ready for holding the bottoms of the forms for the succeeding pour. Forms are raised a panel at a time; accurately lined at the top by means of braces and steel ties; checked for alignment; and then made tight.

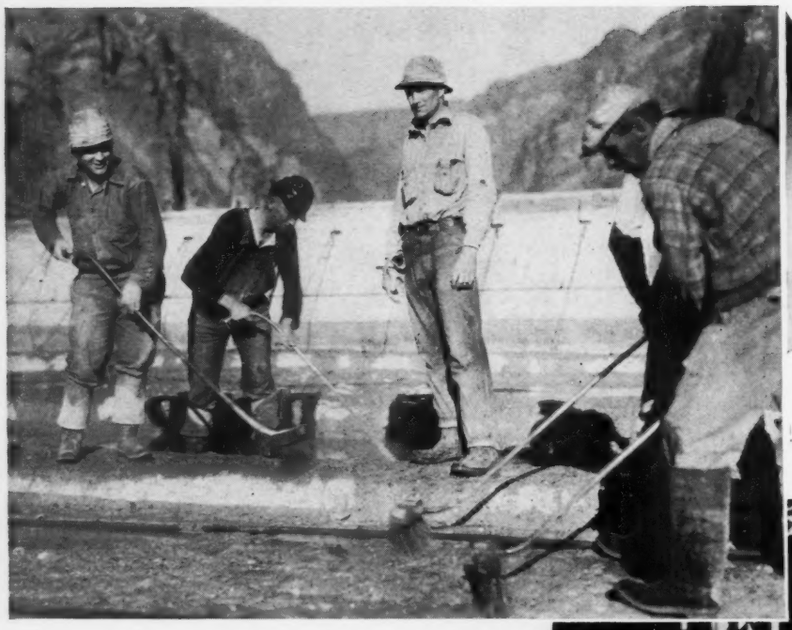
At this point a pipe-fitting crew enters the block to place the grout piping and outlet boxes. The grouting-system tubing varies from 2 inches to ½ inch, outside diameter, depending upon its position. All couplings and tees are of the compression type and are similar to those used with the cooling pipe. The tubing carries the grout from headers to small units located at intervals along both radial and circumferential contraction joints. Half of the grouting boxes required for a contraction-joint section are placed with each of the two pours that are common to that joint. Incomplete portions of the system are carefully capped to protect the piping from damage and to prevent it from becoming filled with concrete and thereby destroying its usefulness for grouting purposes. The piping is arranged so that the radial contraction joints can be grouted separately from the circumferential joints in 50-foot lifts throughout the height of the dam. There are independent supply and return lines in each system so as to make sure that the fresh grout will circulate through the headers and then flow to the risers and through them to the boxes that distribute it in the contraction joints.

Divisions are required at various points to keep the grout in these two systems separate. In addition to a copper grout stop, which is used for this purpose in the interior of the dam structure, a Monel-metal water stop is provided at radial contraction joints at the upper face of the dam. There is also a similar stop at the downstream edges of radial joints below elevation 675, where tailrace water might reach the copper grout stop and corrode it. The specifications require that these stops shall be made absolutely grout tight by riveting and welding. Copper stops are brazed with acetylene torches and bronze rod. Monel-metal stops are welded by means of Westinghouse alternating-current welding machines and Monel rod. After being welded, the grout stops are covered with a layer of asphaltic emulsion which prevents leakage and too tight a bond between them and the concrete, thus allowing the small amount of slippage which is necessary when a joint opens up owing to the contraction of the blocks of concrete on either side of it.

When the grouting system is in position, another crew appears to place the cooling-system piping. This consists of lengths of 1-inch outside diameter, 14-gauge, butt-welded tubing joined by means of compression-type couplings. These are laid on top of the concrete and, to prevent their shifting when the next pour is made, are fastened with wires which have been previously embedded in the surface for that purpose.

An ingenious method is used for protecting the exposed pipe-end couplings at the edges of blocks that are higher than adjacent ones. A small pressed-metal disk, similar to a 6-inch pie plate and having in its center a circular hole through which the end of the coupling is inserted, is nailed to the form with the depressed portion towards the inside of the block. This serves to make a small recess in the finished concrete and provides working space for affixing the coupling by which the end of the pipe extending into it is linked with the adjoining section when the abutting block reaches that level.

When connecting pipe is run in low blocks, a 4-inch plate is placed with its top nesting in the base of the 6-inch plate on the adjoining block, thereby insuring that the coupling will be housed in a space free from concrete and



Bureau of Reclamation photos

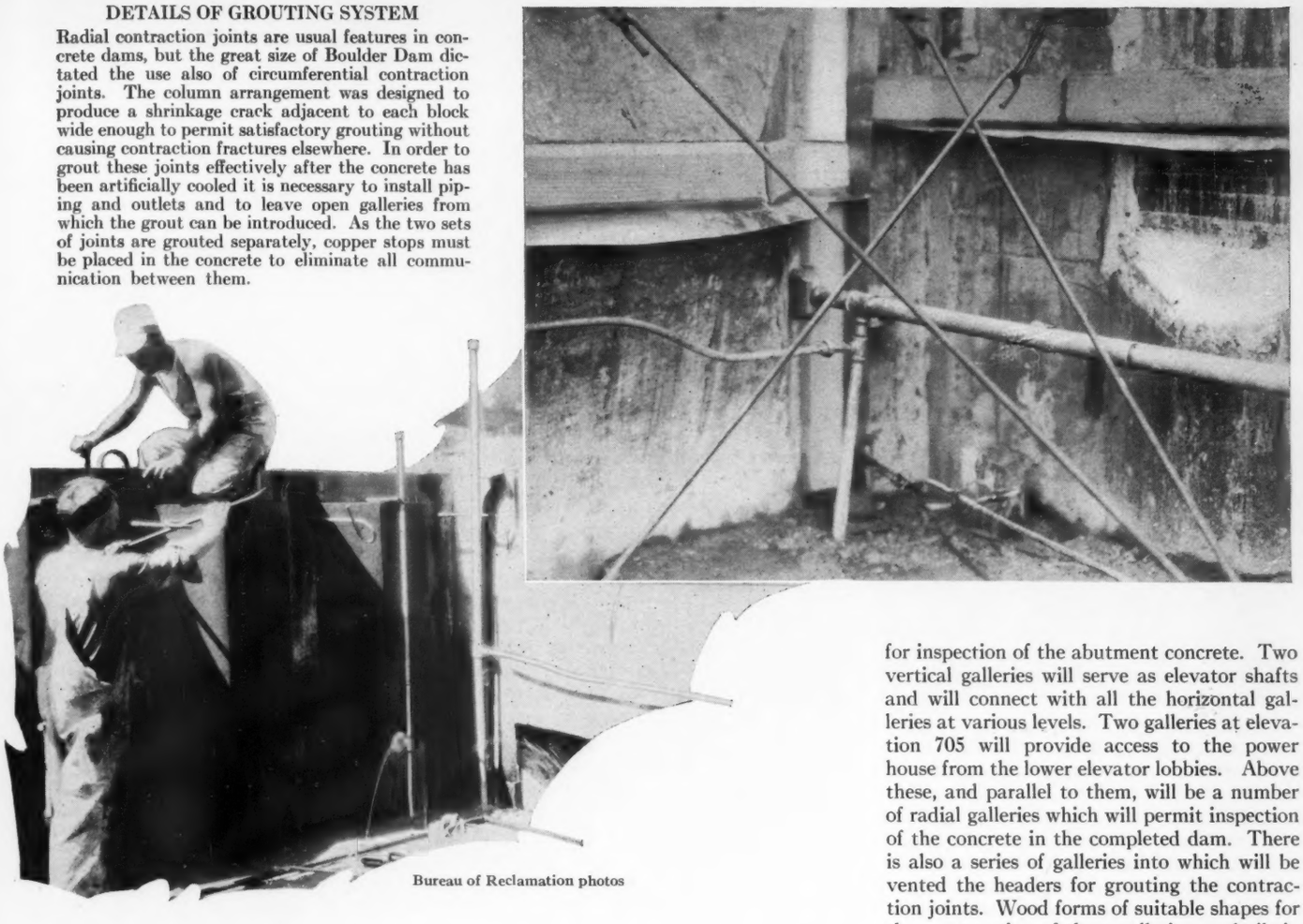
DETAILS OF WORK IN THE FORMS

Each column in the dam is built up 5 feet at a time, with a specified interval between pours. Before fresh concrete is placed in a block, the hardened surface of the previous pour is thoroughly cleaned as an aid in securing a firm bond between the two lifts. A jet of water and compressed air (upper right) exerts a scouring action similar to that of a sand blast, and effectively removes foreign matter and the laitance which forms on new concrete. Sometimes the surface is also brushed with stiff brooms (upper left).

The tramp, tramp, tramp of rubber-booted laborers is the principal means of working the wet concrete in the forms (lower right). Long-handled shovels steady the men and also help in distributing the mix in keyways and around form edges. Compressed-air vibrators (lower left) are used to advantage in working the concrete around and under embedded structures.

DETAILS OF GROUTING SYSTEM

Radial contraction joints are usual features in concrete dams, but the great size of Boulder Dam dictated the use also of circumferential contraction joints. The column arrangement was designed to produce a shrinkage crack adjacent to each block wide enough to permit satisfactory grouting without causing contraction fractures elsewhere. In order to grout these joints effectively after the concrete has been artificially cooled it is necessary to install piping and outlets and to leave open galleries from which the grout can be introduced. As the two sets of joints are grouted separately, copper stops must be placed in the concrete to eliminate all communication between them.



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will be able to act as an expansion joint. Before cooling pipe in a low block is connected with corresponding sections in higher blocks on either side, the flanking sections are blown out with high-pressure water to make certain that they are clear and unobstructed. If plugged lengths are found, the piping in that particular loop is rearranged, if practicable, to provide circulation for the cooling water through as large an area as possible.

Porous drain tiles of 8-inch inside diameter are placed at approximately 10-foot centers in vertical lines along the axis of the dam, extending from a drainage gallery near the base to the top of the structure. As the sections are 2½ feet long, two of them are needed for each drain in a 5-foot pour. This tile is made by Six Companies Inc. in a yard near Boulder City, and is of a special concrete containing, principally, aggregates from ⅛ to ⅜ inch and sufficient cement paste to bind the particles together while still providing a high porosity. The specifications require that each section shall by test pass 4 gallons of water per minute.

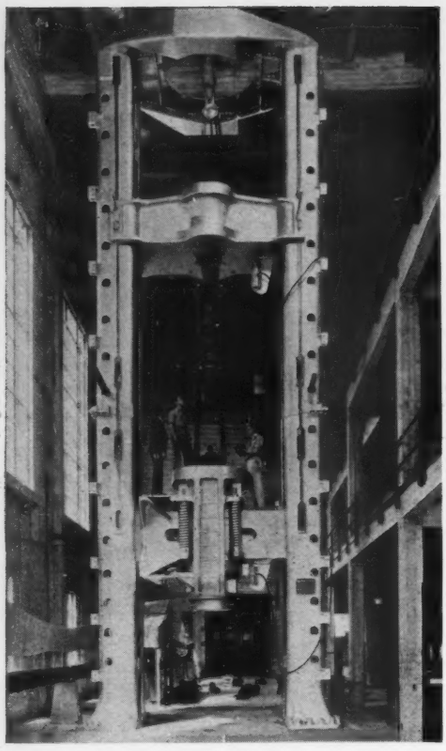
If the form being set up is adjacent to either of the canyon walls, the abutment rock is checked for soundness before any concrete is poured. Inspectors strike it with a hammer or heavy bar, and if it fails to give forth a clear, firm ring it is condemned as unsound and must be removed. As blasting is not permitted in such locations, the loose material is barred down by hand or gouged off with air-driven paving breakers. All the abutment areas were carefully gone over by high scalers during the preliminary stages of the construction, and most of the unsound surfaces that have been encountered since then have been small. Occasionally it is found that weathering has opened or deepened cracks in the rock that were begun by nature or that resulted from blasting during scaling operations. The material which is removed is allowed to fall down on the concrete surface below, where it is shoveled into a rock skip or bucket and moved by cableway to a clean-up car stationed on the railroad trestle, or to a dump truck.

Thermometers, strain meters, and other instruments which must be placed in the dam are inclosed in small receptacles that are embedded in the concrete. A small amount of wet concrete is worked around them by hand in such a manner that they will be protected from damage when pouring from the large buckets is started. These instrument installations require the setting of dowels and bolts and the running of considerable lengths of conduit to carry the connecting wires to the control boxes in the various galleries throughout the dam.

The setting up of forms for the extensive system of galleries constitutes another important accessory operation. One gallery runs along the abutments on either side of the canyon from about the lowest level of the dam clear to the top. It will be used for drainage, for foundation and abutment grouting, and for inspection of the abutment concrete. Two vertical galleries will serve as elevator shafts and will connect with all the horizontal galleries at various levels. Two galleries at elevation 705 will provide access to the power house from the lower elevator lobbies. Above these, and parallel to them, will be a number of radial galleries which will permit inspection of the concrete in the completed dam. There is also a series of galleries into which will be vented the headers for grouting the contraction joints. Wood forms of suitable shapes for the construction of these galleries are built in the contractors' lumber yard at Boulder City and assembled in sections in the various blocks where concrete is poured around them. The grouting galleries are filled with concrete after they have served their purpose and are, in turn, grouted to insure that no open joints remain.

When all the aforementioned auxiliary operations have been performed in a particular block, the surface is given a final clean-up and washing. The block is then inspected and checked by Bureau of Reclamation engineers, who certify as to its readiness to receive the next 5-foot lift of concrete. When approved, the block is posted on the pouring schedule. When the next pour is to be made, the placing crew enters the block accompanied by an inspector, who must be present during the deposition of all concrete. Preliminary to pouring the mass concrete there is applied a 1-inch layer of grout, consisting of sand, cement, and water. The purpose of this is to provide a firm bond between the hardened surface and the freshly mixed concrete.

Through the signalman on the form, the foreman of the placing crew orders the grout from the mixing plant. The bucket in which it arrives is stopped several feet above the form and then opened. The soupy grout strikes the surface with enough force to make it spread rapidly in a thin layer over the entire form area. With brooms and brushes, the crew then works the grout, thus bringing about its firm



EXTENSIVE RESEARCH PROGRAM

Because it was to be the greatest mass of concrete ever poured, Boulder Dam was studied intensively from every angle before construction began. Research in connection with the properties and behavior of concrete was carried on by the Bureau of Reclamation by means of special equipment placed in its Denver offices and also in collaboration with the Materials Testing Laboratory at the University of California where the concrete-strength testing machine shown above is located. Cement is secured from four mills and blended at the dam site to insure uniformity. Aggregates are specially treated and graded, and a high-quality concrete is obtained by using a water-cement content only 2 per cent greater than the void space in the dry rodded aggregates. This concrete, containing 3.96 cubic feet of cement per cubic yard, exhibits a compression strength of 3,200 pounds per square inch after 28 days.

contact with the previous surface and with installed structures. This grouting virtually eliminates the possibility, later, of water percolating through horizontal joints between pours—a circumstance that is believed to be responsible for considerable leakage through many concrete dams.

As described in our November, 1933, issue, an 8-foot vertical slot extending through the center of the dam is left open in pouring the blocks to provide a means for circulating cooling water through the system of pipe coils. As soon as a 50-foot vertical section of the dam has cooled to the scheduled temperatures for that section, the slot within its limits is concreted. The lift is treated in ten successive stages of 5 feet each, with a minimum interval of 36 hours between pours. The concrete is placed progressively from the downstream face to the upstream face of the dam by means of special equipment.

At a level just above the upper limit of the 50-foot lift, standard-gauge rails are laid on stringers supported by 12x12-inch crossbeams wedged tightly at each end into notches cut in the concrete walls of the slot. An 8-cubic-yard car for delivering concrete travels on these rails. Underneath the track are two inverted rails which are hung from the track stringers. These rails, by means of four small trolleys, carry a small hopper and an "elephant trunk," which is a long, flexible pipe for conveying the concrete to the placing areas below. In operation, an 8-cubic-yard charge of concrete is delivered by cableway to the car at the upstream end of the slot. The car is then moved by an endless line, operated by a small hoist, to a point directly above the hopper on the elephant trunk. There the bottom gates are opened, and the concrete flows through the tubing to the desired location. With each successive 5-foot lift, the elephant trunk is shortened correspondingly.

During the excavating for the foundation of the dam, a number of springs were struck, and to dispose of their flow so that concrete placing might proceed, pipes were inserted into the cracks from which the water issued and the cracks were then leaded. The pipes were run in groups to manifolds, and from these headers the water was carried either to the cooling-pipe slot or to the nearest face of the dam. When the time came to concrete the lower part of the slot, it was necessary to transfer the discharge of a number of these drainage pipes to the face of the dam by running individual pipes from each spring system. The flow from some of the springs had ceased, from others it had increased; but it was required that the piping serving all of them be carried outside the dam limits to relieve the pressure on the foundation until grouting and drainage-hole drilling along the axis of the dam could be completed. During the first few pours of concrete in the slot, approximately 20,000 linear feet of small pipe of various diameters, that had been placed there, were embedded to serve as drains for these springs.

Prior to pouring concrete in the slot, the cooling pipes opening from either side of it are washed out and filled with neat-cement grout. Those that leak into the contraction joints are not grouted, inasmuch as grout might escape into the joints and plug some of the tubes of the grouting system inadvertently. The cooling-pipe coils thus left empty will fill with grout at the time the contraction joints are grouted.

After a 50-foot vertical section of the central slot has been concreted, grouting of the contraction joints in that lift is undertaken. The grout is pumped through the headers and distribution pipes to the outlet boxes on the face of each joint. About 50 square feet of circumferential joint area and about 30 square feet of radial joint are served by a box, and the number of boxes is apportioned accordingly.

Researches have indicated that it is possible to obtain a continuous film of grout, entirely filling the contraction joints, having a width of from 0.01 inch to the expected maximum of approximately $\frac{3}{16}$ inch. Special provisions govern the grouting operations. Only cement that passes through 200-mesh vibrating screens is permitted to be used; and, to prevent it from hydrating or forming lumps, storage for longer than ten days after screening is prohibited. It is specified that grout shall be pumped into radial and circumferential joints separately at such a rate as to fill the joint completely in not less than half an hour, and that it shall be circulated in a way so as to insure the removal of all air pockets from the system, to consolidate the grout film, and to press out the water into the concrete of the adjacent blocks. The pressure applied is determined by Bureau of Reclamation engineers, and is usually around 50 pounds per square inch at the grout pump.

Provision is also made for a film of grout between the concrete and rock abutments. The means for doing this consist of headers and risers leading to grout outlet boxes which are similar to those in the contraction joints except that half of the box is provided with a U-shaped iron wire which is grouted into a hole drilled a foot into the rock. This half of the box is supported by a small pad of concrete that holds it in position during the pouring of the adjacent block. The other half of the outlet is placed against the first one and connected to the supply system by compression couplings like those in the contraction joints. The actual grouting of these contacts

EXTREME BOTTOM OF DAM

The trench shown was at the upstream toe of the dam on the Nevada side of the central erosional gorge that the river had scoured in the canyon floor (see page 4390). The bottom of this trench was at elevation approximately 505, and it was here that the lowermost concrete was poured. The network of pipes was installed to carry off the water from the numerous springs that were encountered. Grout will later be forced through these pipes to seal off the flow and to reduce the pressure on the foundation of the dam.

Bureau of Reclamation photo

proceeds in the same manner as in the case of the contraction joints.

Pressure grouting of the dam foundation is required to consolidate the rock and to fill existing cracks. Holes for introducing the grout are drilled in the bottom of the canyon and in the abutments to depths of from 50 to 150 feet. Pressures of from 100 to approximately 600 pounds per square inch will be used in applying the grout.

Supplying power and other utilities at the dam during all these operations is in itself a task of considerable magnitude and cost, since compressed air, water, light, and drainage facilities must be provided for every lift from the bottom of the structure to its full height of 727 feet. Compressed air is now produced at two plants having a combined capacity of about 13,000 cfm. At the height of the drilling program there were three plants with an aggregate capacity of 16,000 cfm. The two plants now in use are approximately two miles apart, both on the Nevada side of the river, and are connected by pipe line.

From the air main, branch lines are carried up the upstream face of the dam on brackets and up the downstream face in the slot which houses the cooling-water supply and return pipes. Branch air lines are also installed in the galleries, and from them risers, cast in the concrete, extend to the pouring surfaces.

CONCRETING CENTRAL SLOT

The 8-foot central cooling slot is concreted in vertical lifts of 50 feet each after the dam sections on either side have been cooled. Concrete is delivered in buckets by cableway to the upstream face of the dam and there transferred to the car shown here. This car runs through the slot on tracks and discharges into a hopper from which flexible tubing extends downward to the pouring area. The 50-foot lift is divided into ten 5-foot pours, with a minimum of 36 hours between pours.

From these principal delivery lines, laterals are run to various areas throughout the dam to supply manifolds having approximately twenty outlets to which hoses are attached as air is required for various purposes. Compressed air is primarily used for operating "Jackhamers" in drilling anchor holes for abutment grout boxes, anchor form holes, and light-bracket holes in the canyon walls; for running paving breakers in scaling down loose wall rock; for operating drills and other wood-working tools on the forms; and for the air-water jets that serve to clean the top surfaces of blocks.

Water supply and distribution must also keep pace with the concreting operations. Water for all constructional purposes is obtained from four wells sunk in the river bottom. There are two of these upstream from the dam and two on the downstream side. By means of manifolds and cross connections, water from any of these sources can be delivered almost anywhere on the job. In general, the upstream wells supply the Arizona and Nevada spillways high on the canyon walls above them, as well as the upper portion of the dam, and, during high-water stages of the river, form an emergency source of mixing water for the Lomix plant. The downstream wells supply the lower part of the dam, the penstock tunnels, and the valve-house benches, and furnish make-up water for the cooling tower of the refrigerated-water system.

A 6-inch water line parallels the 4-inch air main in the central slot up the downstream face of the dam. A water main also is carried up the upstream face of the dam. From these two risers extend branches to various areas and supply manifolds having approximately twelve hose connections. The principal uses of water are for curing the concrete and for cleaning operations, which have been described. Water for curing is applied in two ways: the vertical faces of concrete are kept moist by sprays issuing from 1/8-inch holes in a 1-inch pipe hung at the lower edges of the form panels. These pipes are moved upward when the panels are shifted, and require no attention from the waterman other than to see to it that the connections are made and that the flow of water is uninterrupted. Top surfaces of concrete blocks which are not being worked upon are kept continually moist by several men with hoses. Each man makes a complete circuit of the section of the dam assigned to him often enough so that no block will become completely dry before it is again sprinkled. The pumps deliver the water under sufficient head to provide a pressure of about 150 pounds per square inch at the working surfaces of the dam. This is required for cleaning, and is also desirable for sprinkling, as it enables a hoseman stationed on a high block to reach a number of surrounding lower blocks without the need of moving from block to block under difficulties.

Lights are essential to the successful pouring of concrete at the high rate that has been maintained thus far. Illumination has been so effectively provided that operations can be carried on as well by night as by day. Many auxiliary tasks such as laying pipes are done principally by the day shift, leaving the swing and graveyard shifts to concentrate on pouring; and an examination of the records has disclosed that the night workers have generally placed more concrete per shift than the day crews.

FRACTIONAL FORM

Where the concrete abuts against canyon walls, irregularly shaped blocks result. Areas that are too small to admit the bottom-dump buckets ordinarily used are poured by means of special buckets. In the triangular form against the wall can be seen the vertical risers for grouting the joint between the concrete and the rock. The form shows how vertical keyways (left) are produced for interlocking radial contraction joints. Grout riser pipes can be noticed at intervals along the near side of this form.

Two types of lights are used: those that are semipermanent, and those that must be moved with each pour to give increased illumination in localized areas. The fixed lights are mounted on brackets on the canyon walls and are attached to the upper and lower catwalks across the canyon. These have large industrial reflectors, fitted with 1,000- or 1,500-watt globes, and are usually set in banks of three or six at each location. Local lights are of the portable flood-light or so-called dishpan type which has attracted wide attention among tourists. They are mounted on brackets or tripods and secured to any convenient structure in an area where men are working. Sets of small lights are also required inside the galleries where electricians make up the leads from the instruments to their respective terminal boards; along the several levels of the walkways in the central slot where the pipefitters make and change connections to the cooling-pipe headers; and at various points in the layout of blocks that is complicated on the downstream face of the dam by the power-house foundation.

Another important service is that of transportation for the workers. An inclined skip accommodating fifteen men is provided at the downstream face and two similar ones at the upstream face. These are railed platforms

which are moved up and down the face of the dam on greased skids by 75-hp. motors. The hoist operator is in full view of the slides from top to bottom, and the workers give their signals directly to him. There is also a skip-way extending from the rim of the Nevada abutment down to elevation 850. This aids the men in getting to and fro, and is also used for carrying materials. It has a capacity of 50 persons. Among the workers these elevators are known as "monkey slides." In order that it may not be necessary for the men to climb up and down ladders when going from one high block to another across an intervening low block, a light-weight foot bridge has been devised. One man at each end can handle one of these readily, and they are put in position while the forms are being raised.

The disposal of waste and the drainage of water from a series of high and low blocks is somewhat of a problem. Rock scaled from cliffs, lumber scraps, and debris of all sorts are cleared from high blocks and deposited on the lowest adjacent block, which becomes a catchall. At the collection point the waste is placed in a skip or bucket and removed by cableway.

Clean-up water is disposed of by means of a unique drainage system cast in the concrete of the dam. Water from high blocks is allowed to drain through holes in the forms to adjacent low blocks. Each of the latter opens at its lowermost point into a 4-inch vertical drain that is embedded in the concrete and connects with a 6-inch header that is almost horizontal. This carries the water to the nearest dam face. The openings into the drains are protected by conical screens to exclude particles of rock. This waste water is collected in a sump. If it settles clear, it is returned by a sump pump to the suction of the high-pressure pumps for re-use on the dam. Otherwise, it is pumped to a diversion tunnel that discharges into the river.

The coördination of these manifold operations and detailed tasks incidental to the actual pouring of the concrete is the real masterpiece of organization in connection with the contract. Principal credit for the smooth-working system which is resulting in record-breaking progress is due General Superintendent F. T. Crowe. Upon his shoulders the directors of Six Companies Inc. placed the chief responsibility for carrying out this huge undertaking. With the help of his able assistants he has set new concrete-placing speeds.

The program outlined by Mr. Crowe is being put into effect by A. H. Ayers, chief engineer, and by Bernard "Woody" Williams, assistant general superintendent, and their respective staffs. The field organization was selected with the same care that was exercised in the preparation of the construction plan. It is impossible here to mention more than a few of the keymen who are contributing to the successful outcome of this largest construction job ever undertaken in behalf of the Government.

Karl Collett, Frank Bryant, and Ed Wattis have charge, respectively, of the graveyard, day, and night shifts. Tom Price is superintendent of the gravel plant and the railroad, and in that capacity he oversees all operations having to do with the concrete aggregates from the time they are excavated from the gravel pit nine miles up the river until they are delivered ready for use to the two mixing plants. Dave Williams is in charge of the cableway operations and rigging. Ira Carpenter supervises the operation of the two concrete-mixing plants. The placing of pipe in the dam, the maintenance of air and water lines leading to the dam, and the water-supply system are directed by A. L. Reed, pipe foreman. The operator of the compressor plants and of the concrete-cooling-water system is Gus Larson. C. A. Harris, chief electrician, and his crew keep power on the line for the motors of the cableways, mixing plants, and pumps, and maintain the lighting system as well as the telephone system between signalmen and cableway operators. Cy Bous, master mechanic, and George L. Malan, machine-shop foreman, are responsible for keeping the equipment in condition for highly efficient work.

Such plant engineering as is required in connection with the contract—the designing, for example, of cableways, mixing plants, railroad trestles, derricks, forms, etc., etc.—has been done by the engineering department of Six Companies Inc. directed by Mr. Ayers and by J. P. Yates, the office engineer.

Only through the unified effort of these men and of countless others has it been possible for Mr. Crowe to achieve the high degree of coördination which is reflected in the noteworthy records that are being made. The completed dam not only will bear testimony to the sound judgment of those courageous individuals who envisioned the structure many years ago but will also constitute an enduring monument to the unity of purpose and unflagging energy of the personnel of Six Companies Inc., from the highest to the lowest.

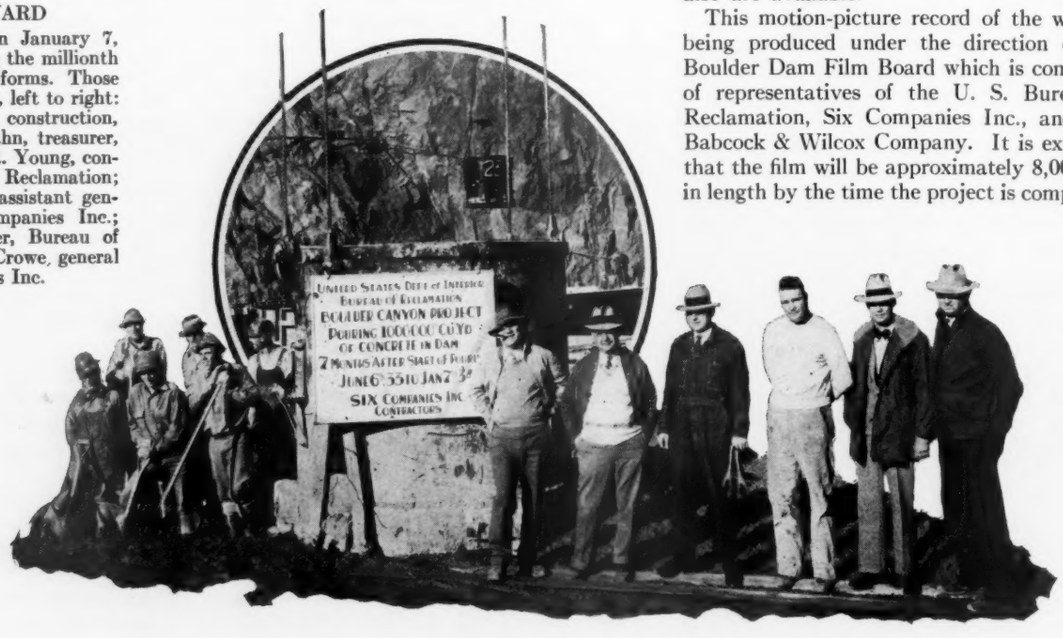
MOTION PICTURES TELL STORY OF BOULDER DAM

THE interest in Boulder Dam throughout the country has created a surprising demand for motion pictures of the construction operations. In an effort better to meet the many requests for the official Government progression pictures, the handling of them has been turned over to a private enterprise designated the Boulder Dam Film Library. This concern is doing business in Boulder City, Nev., under a Government permit which binds it to carry a sufficient number of prints of the film to supply the calls that are received. The films, which are available in either 16 mm. or 35 mm. size, cover all phases of the work completed to date. Their 4,000 feet of length represents the edited version of some 16,000 feet that has so far been taken. A nominal rental charge is made for these pictures. Short films, 100 to 400 feet long, which depict individual phases of the operations, also are available.

This motion-picture record of the work is being produced under the direction of the Boulder Dam Film Board which is composed of representatives of the U. S. Bureau of Reclamation, Six Companies Inc., and The Babcock & Wilcox Company. It is expected that the film will be approximately 8,000 feet in length by the time the project is completed.

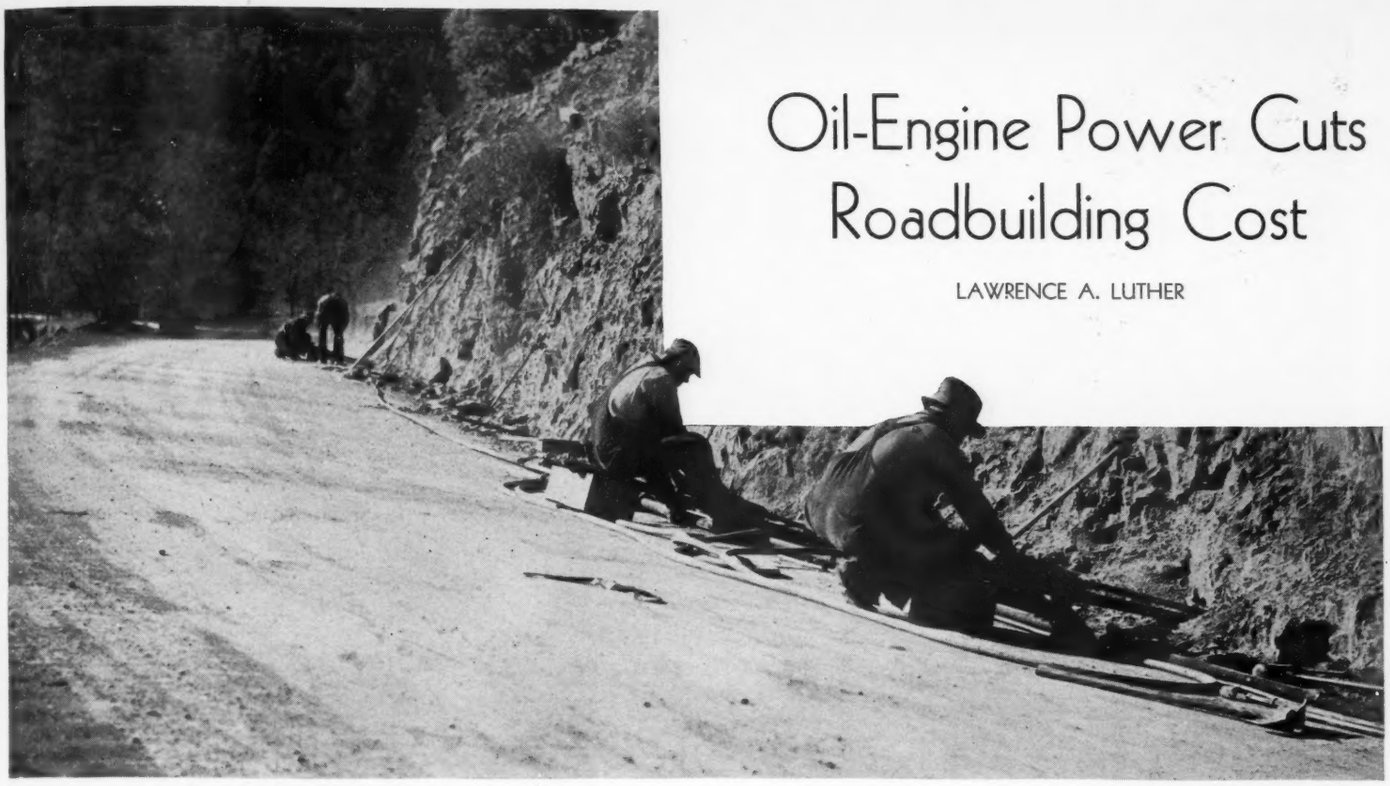
THE MILLIONTH YARD

Work paused long enough on January 7, 1934, to permit photographing the millionth yard of concrete placed in the forms. Those lined up in the foreground are, left to right: Charles A. Shea, director of construction, Six Companies Inc.; Felix Kahn, treasurer, Six Companies Inc.; Walker R. Young, construction engineer, Bureau of Reclamation; Bernard "Woody" Williams, assistant general superintendent, Six Companies Inc.; John C. Page, office engineer, Bureau of Reclamation; and Francis T. Crowe, general superintendent, Six Companies Inc.


UNITED STATES DEPT. of INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
POURING 1000000 CU YD
OF CONCRETE IN DAM
7 MONTHS AFTER START OF PLACING
JUNE 6 '33 TO JAN 7 '34
SIX COMPANIES INC
CONTRACTORS

Oil-Engine Power Cuts Roadbuilding Cost

LAWRENCE A. LUTHER



WIDENING OLD ROADWAY

In some places where the new grade follows the old one, the existing roadway is widened by drilling toe holes in the slope on the uphill side and blasting out overlying material. For this work there are being used four S-49 "Jackhamers" operated by one 370-cfm., oil-engine-driven, portable air compressor.

THE STATES of the Pacific Coast are rapidly straightening, leveling, and paving highways which at the turn of the century were mere trails or wagon tracks. Typical of this evolution of the roads leading into the hinterland is the history of the route between Redding and Alturas, Calif. Long stretches of it originally were Indian paths, and it took on its first semblance of a road when Federal troops had reason to use it while campaigning against several unruly tribes which made their final stand in this rugged section between the Cascade and Sierra ranges. Occasional venturesome pioneers who sought homesteads in the picturesque valleys also contributed to the early improvements. At the insistence of growing settlements in Oregon and California, the Federal Government, in 1850, sent General Crook into the region, and he established Fort Crook near the site of the present Town of Fall River, about 70 miles northeast of Redding. Some of the sons and daughters of Crook's volunteers still live along the old road, and their reminiscences of frontier life and of the frequent brushes between the settlers and Indians serve as vivid reminders that this area was a vast wilderness only a few years ago.

Following Marshall's discovery of gold in Sutter's millrace, prospectors swarmed into this remote watershed of the Sacramento River; and, although the ground proved less productive than the gold-bearing gravels of the Sierra, several good claims were located along the Pit and McCloud rivers and their tributaries. From the mines which were then opened up, silver, lead, zinc, and other metals were produced up to as recently as 1926.

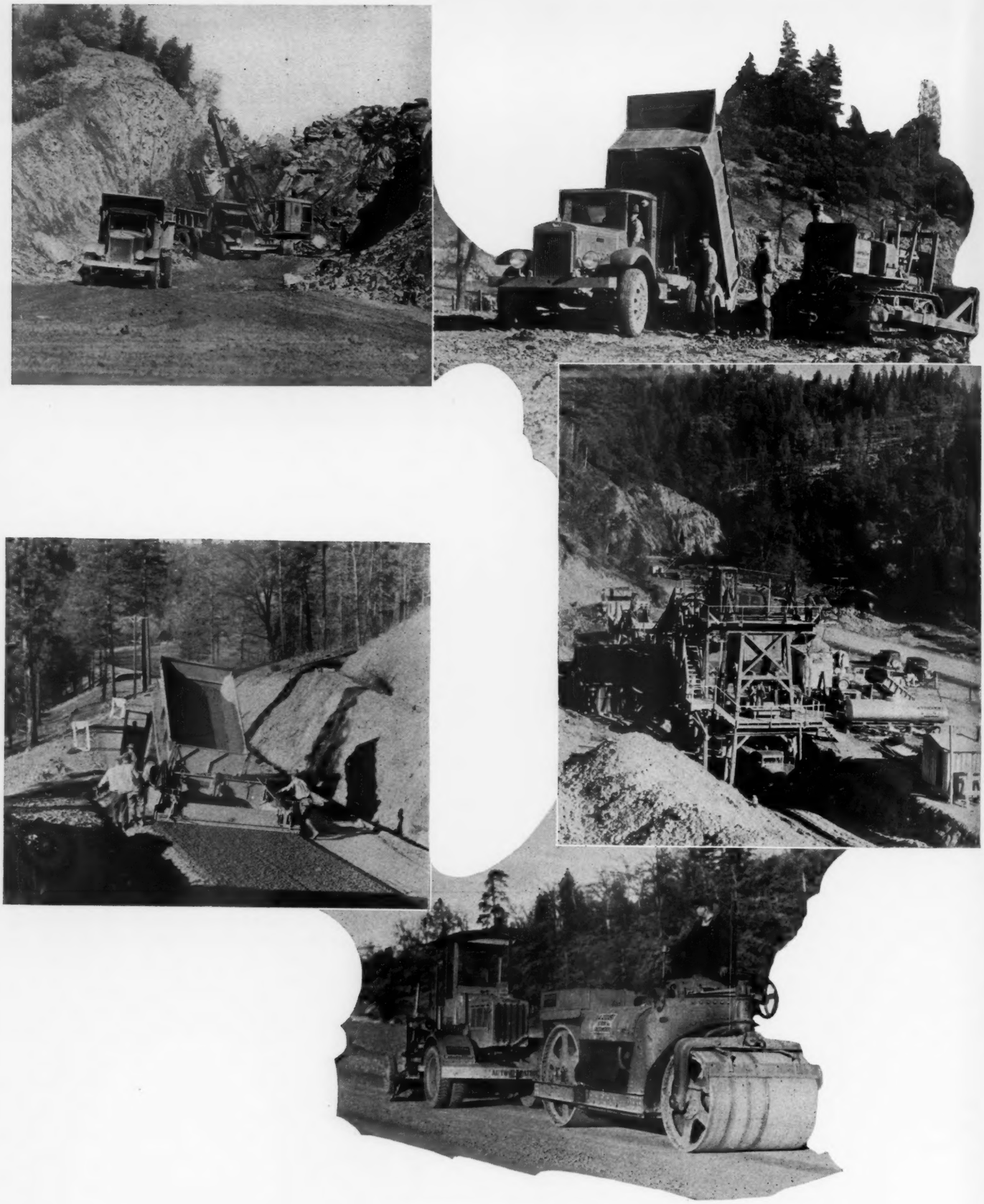
If the plans for the $170,000,000 Kennet Dam materialize, a many-fingered lake of sparkling mountain water will cover a large area in the heavily wooded valleys, and will increase the attractiveness which the region already holds for hunters, fishermen, and vacationists. Mule deer, bears, and pumas are still fairly plentiful, and both trout and salmon inhabit the streams. The improvement of this road, which runs diagonally across the section between Mt. Shasta and Mt. Lassen, will make a large area of near-virgin mountain country accessible to San Francisco by a 1-day drive, and will bring that city considerably closer to two national parks and a forest preserve.

The old wagon trail followed the shortest negotiable route, and a few of its stretches are still very winding and steep. Many betterments in grade and alignment were made with convict labor in 1920, but much remained to be done when work was lately resumed with funds appropriated under the Federal Public Works Program. The scheduled improvements call for relocating considerable portions of the highway and for building a wide, high-gear road throughout its length.

The firm of A. Teichert & Son, Inc., of Sacramento, Calif., is now engaged on a contract under this program which involves the surfacing of 15.9 miles of roadway south of Montgomery Creek and the widening or relocating of a 1.5-mile stretch. This latter phase of the operations calls for excavating and handling 86,000 cubic yards of unclassified material. The usual regulations governing the working conditions that are being applied to all Federal Emergency Road Projects are in force. Laborers are drawn from Shasta County; are limited to 30 hours of work a week; and are paid a minimum of 60 cents an hour.

When completed, the highway will have an average width of 24 feet. On the section under discussion, the surfacing consists of a base of crushed gravel slurry from 2½ to 7 inches thick, and of a seal coat of ¼ to ½ inch screenings. The surface is consolidated with a heavy fuel-oil binder. Material for the base is dredged from Cedar Creek with a 1¼-yard P&H shovel and trucked to a screening and crushing plant. Bowlders are crushed in a Wheeling jaw crusher. The product is screened, and rejected material is recrushed in a Telsmith cone crusher. After mixing, the slurry is delivered by chutes from a storage bin to trucks, hauled to the job, and distributed on the surface with two Spearwell Hembell spreaders. Screenings for the seal coat are placed with the aid of Spearwell spreaders, and binder oil is applied by a tank truck equipped with spray nozzles. Finishing operations consist of blading with Caterpillar Motor Patrols, followed by rolling.

An interesting feature of this contract is that the crushing plant and all motorized equipment except trucks use oil as fuel. This is, of course, merely one more manifestation of the growing trend towards realizing a maximum of power economy in field operations. It is interesting to recall in this connection

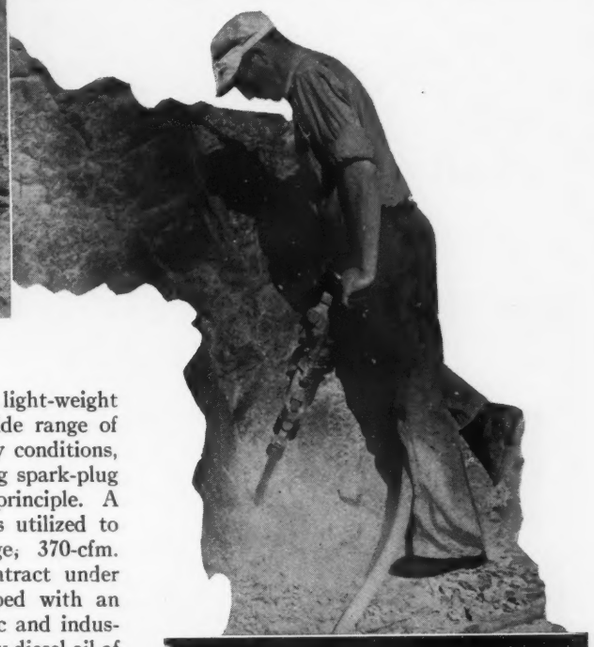


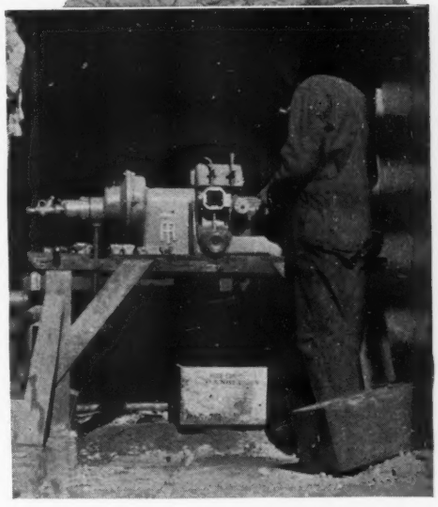
A SEQUENCE OF OPERATIONS

Material from cuts is loaded into trucks (upper left), dumped in fills, and there spread by means of a "bulldozer" mounted on a Caterpillar tractor (upper right). Slurry for surfacing the completed grade is dredged from a stream and then run through a crushing and screening plant (right-center). The slurry is trucked to areas of application and distributed over the surface with Spearwell Hembell spreaders (lower left). A base coat is placed first, and, on top of it, a seal coat of screenings. Binder oil is then sprayed over the surface, which is bladed and rolled (lower right). The completed highway will have an average width of 24 feet.

MODERN DRILLING PRACTICE

In addition to availing himself of the economies of the oil-engine-driven compressor, the contractor on this roadbuilding job is making further savings by using detachable "Jackbits" for all drilling. By resharpening bits before they become badly worn, each is used on an average six times before being discarded. Shown here are a typical drilling scene, the "Jackbit" grinder, and the portable compressor which is being operated at a fuel cost of 30 cents an hour.





that the internal-combustion engine was first applied to contractors' equipment scarcely twenty years ago. Doubts were expressed at the time, even by machinery manufacturers, themselves, that the innovation would receive anything like general acceptance. Illustrative of this attitude was the feeling among compressor makers that few contractors would be induced to buy expensive gasoline to use in the then unconventional portable compressor for producing any considerable quantities of compressed air. Yet it was largely because of the introduction of such units that compressed air reached its present stage of almost universal use wherever rock has to be excavated, rivets driven, or various other operations performed. Their influence was, in fact, so great as virtually to recast the basis of figuring on all contracts involving construction work.

While the gasoline engine was avidly accepted in the United States, the high cost of gasoline proved a stumbling block in various other countries. Europeans were quick to see the advantages of the internal-combustion engine, and it was only natural that they should take the lead in developing types which could be operated with low-cost fuel oils.

It became evident some time ago that fuel-oil engines of small and intermediate sizes had been brought to such a high stage of operating efficiency and reliability that there was a distinct place open for them in this country, notwithstanding the relatively low cost of gasoline enjoyed here. Manufacturers of construction equipment were among the first to take advantage of this situation; and it is significant to note that, whereas the automotive industry led the way in the development of the gasoline engine, the heavy-machinery industry is popularizing the fuel-oil engine.

The problem of designing satisfactory fuel-oil engines has been complicated by reason of the changing practices in the refining of petroleum, because not only do fuel oils vary as between refineries but even the product of the same plant differs in characteristics from year to year. Accordingly, the available fuels, or those that are most economical to use, are not the same the world over.

To overcome these difficulties, a light-weight engine, capable of burning a wide range of fuels smoothly under all ordinary conditions, has been developed by combining spark-plug ignition with the solid-injection principle. A 4-cylinder engine of this type is utilized to drive an Ingersoll-Rand 2-stage, 370-cfm. portable compressor on the contract under discussion. The unit is equipped with an electric starter and uses domestic and industrial fuel oils Nos. 2, 3, or 4, or any diesel oil of suitable viscosity. The machine furnishes air for operating four S-49 "Jackhamers" at a time, and maintains a pressure of between 75 and 90 pounds. Holes are being drilled to a maximum depth of 20 feet; and, except for halts for changing steel and miscellaneous delays, the drills are operating continuously.

The compressor uses on an average 5 gallons of fuel oil per hour costing six cents a gallon. It was operated for some time for three 5-hour shifts daily. As compared with a late model, 2-stage, gasoline-engine-driven portable burning gasoline at fourteen cents a gallon, it is estimated that this unit has shown a saving of $238 in fuel cost per 26-day month. If the comparison were made with a conventional single-stage portable compressor of equivalent output the estimated saving per month would come to $375.

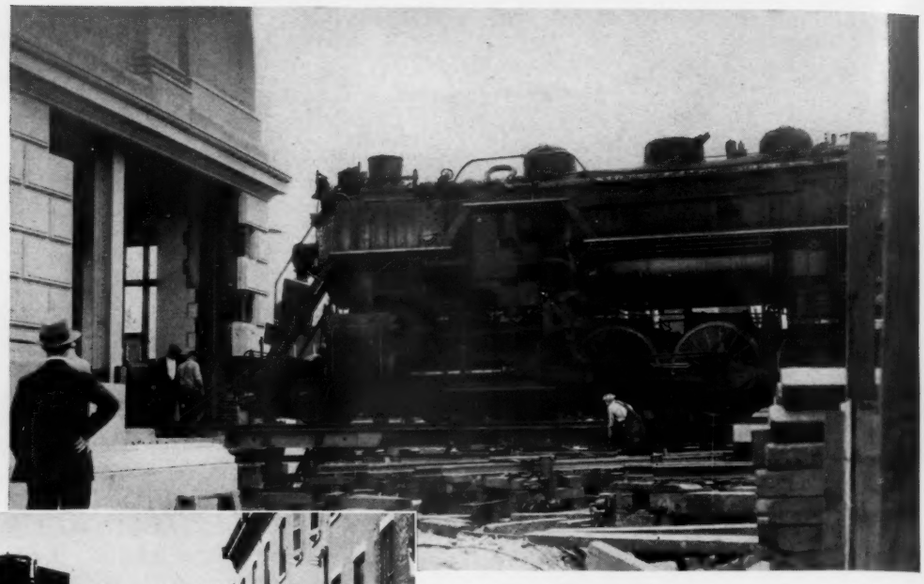
As these figures take into account only the compressor, it is obvious that similar comparative operating costs of other machinery on the job equipped with fuel-oil engines would reveal an aggregate economy of considerable amount. It has been found that the adoption of oil-engine drive has not materially affected the weight or flexibility of any of the units being used, and no difficulties have developed with regard to starting or maintenance.

The rock being drilled ranges from hard lead ores to shales. To meet these diversified conditions, either 20 per cent or 40 per cent Trojan granular dynamite is employed in either coyote or lifter holes. The material broken up by the blasts is loaded by a 1¾-yard Northwest shovel into one International 6-yard and three Mack 7½-yard dump trucks.

All drilling is done with "Jackbits"; and by installing an air-operated J-2 "Jackbit" grinder it has been found possible to resharpen them on an average six times. From 2 to 15 feet of hole is obtained with a bit before regrinding it. It is the practice always to redress bits before they have become seriously worn, and it is the opinion of those in charge of the work that this results in the following economies: a material increase in total footage of hole drilled per bit; straighter holes and fewer stuck steels; lower loss of drill efficiency from using dull bits; and less rapid and less damaging wear on grinding wheels.

For the information contained in the foregoing account, acknowledgement is made to A. Teichert, Jr., president of A. Teichert & Son, Inc., and to A. E. Hullin, superintendent.

Moving a Locomotive through City Streets



SPECIAL DELIVERY

There are probably few more forlorn and unwieldy objects than a locomotive with drawn fire and without tracks to run upon. The accompanying article describes how a 266-ton "iron horse" was moved four blocks through a busy city to become a museum piece. One problem was to distribute the weight so that the pavement and adjoining property would not be damaged. This was done by constructing two tracks side by side, and by supporting the locomotive on rollers that were long enough to bear upon both sets of rails. The picture at the left shows the engine *en route* to its new home. Upon its arrival at the museum (above) it was run into the building through a gap in the wall that had been left open for that purpose.

Baldwin Locomotive Works photos

WITH steam in its boiler and rails beneath its wheels, a railroad locomotive can eat up miles at a fast clip; but without a fire and minus tracks on which to run it becomes an unwieldy object, indeed. Yet, occasionally, it is desirable to move a locomotive under such conditions, and then it falls to the lot of a specialist to accomplish the job.

Such an instance occurred recently in Philadelphia. The Franklin Institute wanted to add to its railroad display a full-sized, modern locomotive which it had secured from the Baldwin Locomotive Works. Its new building, which has just been occupied, is in the heart of the city and four blocks from the nearest railroad tracks. It was neither economical nor feasible to lay connecting rails, so a contract for delivering the locomotive safely inside the walls of its new home was awarded to the John Eichleay, Jr., Company, which makes a business of moving buildings and other bulky objects.

To lighten it, the locomotive had been relieved of its water and fuel; but, even so, it weighed 210 tons and its tender 56 tons—a total of 266 tons. The simplest and quickest method of moving it would have been to lay temporary tracks on the street; but to safeguard the pavement and the structures beneath and on either side of it from damage, it became necessary to distribute the load to a greater extent than this plan would have permitted. The following description of how the contractor met the problem is quoted from the publication *Baldwin Locomotives:*

"The locomotive and tender were run from the railroad track directly on to tracks mounted on cradles or platforms constructed of steel beams. The wheels were then blocked and secured to the cradles so that they could not turn. Planks were laid in the street, and on these a section of double tracks was laid, using wooden crossties and steel rails. The cradles and their load were then moved along this temporary track on steel rollers similar to those used for moving houses."

Despite the great load that rested upon the pavement, it was distributed so that at no point did it exceed the weight customarily imposed by motor trucks, which use it continually. The actual moving of the locomotive was effected by a motor truck. It was slowly towed the length of the double-track section on which the rollers rested, after which a halt was made until the portion of the track behind the locomotive could be taken up and relaid in front of it. Several busy streets on which trolley cars were operating and on which motor traffic was heavy had to be crossed, and these intersections in its course were covered late at night and early in the morning so as to interfere as little as possible with the usual use of those thoroughfares. It required nearly a week to traverse the four blocks.

In order that the locomotive might be run into the building with facility, a large opening had been left in one of the museum walls. Inside the structure a special flooring had been laid to receive the load. The section where it was to stand was supported on its own foundation, separate and distinct from that which carries the building walls. The locomotive tracks are built over and rest upon six different types of bridge construction which were placed there for experimental purposes. By means of special testing apparatus, the effect of the locomotive's weight upon each of these was recorded.

The locomotive which has now become a museum piece is No. 60000. It is a 3-cylinder, compound type, with a water-tube fire box, and was built in 1926 for experimental purposes. Although it remained the property of the manufacturer, it was tried out during the intervening period by some of the country's leading railroads. The exhibit of which it is now a part consists of models of early locomotives used in the United States and England, and of full-size specimens of various types. Among the latter will eventually be included the *Conestoga*, built in 1844 for the Reading Railroad, and other pioneers in the nation's railroad transportation.

Making an Old Bridge Lighter

R. G. SKERRETT

LIGHTENING THE LOAD

By replacing the steel floor system of the Smithfield Street Bridge with aluminum-alloy members, Pittsburgh deferred building a new bridge for probably 25 years and made an estimated saving of $1,564,875. Each of the 26 panels in the structure was reduced in weight 28.9 tons, representing a total reduction of 751.4 tons. This lessening of the dead load enables the bridge to bear much greater live loads than formerly and has resulted in the removal of restrictions on the weights of trucks and street cars using it. The picture above shows the bridge before the two midstream spans were renovated. The workman at the right is carrying an aluminum-alloy channel 21 feet long. It weighs 104 pounds as compared with 292 pounds, the weight of a steel channel of the same size.

NEW wine in old bottles? The very height of unwisdom! At least so has said tradition; and many and varied have been the applications of that warning. Even so, engineers have recently made light of that ancient saw in the case of an old bridge across the Monongahela River at Pittsburgh, Pa. Strange as it may seem, while still retaining its original supporting members, the bridge otherwise has been so transformed as to make it better than it was at any time in the past and to extend its useful life for a full quarter of a century to come.

The river crossing in question is the Smithfield Street Bridge which was erected 52 years ago and serves as a highway between the most bustling part of the business section of Pittsburgh and what is today known as the South Side—a subdivision of the greater "City of Steel," and a rapidly developing one. The structure has been of continually increasing importance ever since it was built, and it has been expanded laterally twice to provide more space for augmenting traffic. It has two roadways—one for street cars and one for vehicles —and two broad flanking sidewalks. One has but to see it in service during rush hours of any week day to realize its value to the community.

The Smithfield Street Bridge was designed by the eminent bridge engineer, Gustav Lindenthal, and erected under his supervision. At that time he showed a pioneer faith in steel by utilizing some of that metal for certain of its features, but for the most part he employed the more familiar wrought iron. The midstream section of the structure is made up of two spans, each 360 feet long, consisting of four elliptical trusses arranged in two parallel lines and from which were suspended a succession of hangers to which the floor system was secured. Thus built, the bridge was 25 feet 8 inches from center to center of the trusses and had a single roadway with a walkway projecting from each side.

The crossing was only eight years old when it was found desirable to widen it 20 feet 8 inches on the upstream side. The necessary support for each span was provided by an additional elliptical truss, and the beams for the added breadth of the floor system were spliced to the corresponding original beams—the splicing being done on the upstream side at a point a few inches out from what became the center line of the bridge. Along in 1911, the floor was widened 4½ feet more on the same side. By that final enlargement space was made available on the upstream half for two electric-car tracks, while the other broader roadway was assigned exclusively to vehicular traffic. This was the city's answer to the ever-growing volume of motor traffic.

The walkways were floored with a single course of 2-inch planking, and the vehicular highway was decked with three courses of timber having a total thickness of 11 inches. There were also walkways along the street-car tracks. All this timber was a fire hazard; and more than one of Pittsburgh's bridges had

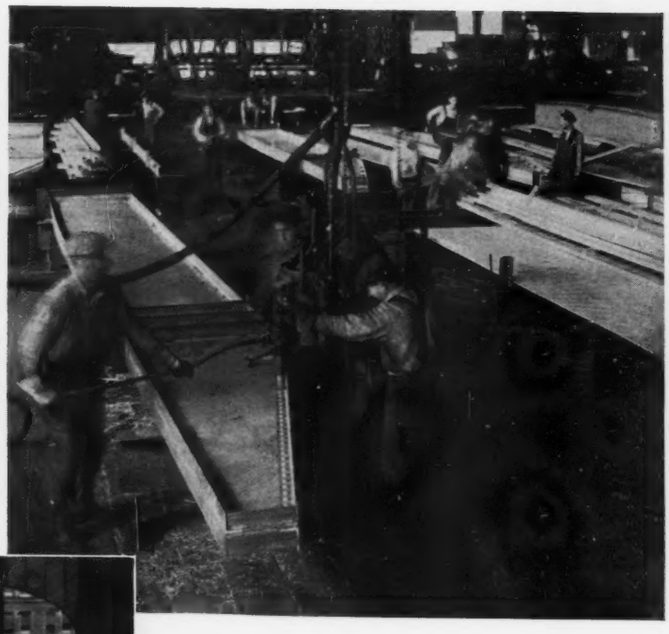
STEPS IN THE WORK

Details of the floor structure on one side of the bridge just prior to laying ties and rails upon it are pictured above. Floor slabs for the highway side of the bridge were assembled in the shop and then moved into position (right). The slab shown is 11 feet wide and approximately 27 feet 8 inches long. Two such slabs, placed side by side, form the deck of a floor panel. The completed deck of the highway side of the bridge (upper right) was paved with cold-mix asphalt. Rivet heads and the hatched surface of the plates help to prevent the pavement from "creeping" under traffic.

been destroyed or gravely damaged by flames prior to 1911. Not only that, but the wear and tear on the decking entailed frequent and often costly repairs. Those outlays would probably have been accepted as unavoidable and not especially deserving of emphasis had not increasing traffic caused studies that brought out the fact that the supporting trusses were being subjected to excessive stresses. That was in 1926; and two years later the Department of Public Works strengthened the central as well as the upstream trusses by welding steel bars to one face of each of them. This did make them better able to meet service conditions, but it did not lessen the dead load on the trusses. The municipal engineers were just bent upon helping the bridge to tide along for a few years more, being convinced that it was merely a question of a short time before the structure would have to be condemned and a new one erected to take its place. Incidentally, restrictions were placed upon the heavier traffic, and this applied particularly to the electric railway.

Matters came to a critical pass in 1932, when a close examination of the entire bridge disclosed the need of numerous repairs to different parts of the structure and of the renewal of the wooden decking. With funds difficult to obtain, Chief Engineer Charles M. Reppert and his associate experts in the bridge division of the Department of Public Works grasped the fact that there was but one way to retain the river crossing in service at a relatively moderate expenditure, and that was by scrapping the whole floor system and by replacing it with one that would be much lighter. It was recognized that the essential structure of the trusses was generally sound and equal to carrying a new floor if sufficient weight could be saved. At the same time, if successful in this effort, the current permissible volume of traffic could still continue to use the bridge when renovated as contemplated.

The stumbling block to the project lay in finding structural plates and shapes that would be both light and strong; and after much planning and estimating it was evident that steel would not meet these somewhat conflicting requirements. This brings us to the point where metallurgical research saved the situation and, incidentally, opened the way to a departure of momentous significance in structural engineering. At the crucial moment, when the municipal bridge engineers were puzzled, their attention was called to an aluminum alloy that had been developed by the Aluminum Company of America and used successfully for several years in work demanding both lightness and strength—that is, in the construction of traveling cranes and dragline booms, of automotive vehicles, and, still later, of special cars for railway service. Aluminum alloy "17 ST", as it was designated by its producers, had amply demonstrated its outstanding qualities to the satisfaction of everyone concerned; and the experts of the Department of Public Works of Pittsburgh immediately started to design a new floor system for the Smithfield Street Bridge embodying plates, angles, and other shapes of "17 ST". In short, the floor members were to correspond



USES OF COMPRESSED AIR

The various members of the floor system were successfully fabricated in a shop that was equipped for similar work with steel. Riveting was used throughout, as the characteristics of aluminum alloy do not permit it to be welded. Because of the comparatively greater cost of aluminum alloy as against steel, especial care was taken in shop operations to minimize losses of material. As the upper pictures show, pneumatic tools such as are ordinarily used in fabricating steel were extensively used in the work. Air-driven paving breakers (left) facilitated tearing up the three courses of timber decking on the highway side of the old bridge.

with those of steel generally employed but with a very substantial saving in weight through the adoption of the aluminum alloy.

In this designing the Aluminum Company of America collaborated by developing ribbed-deck slabs for the highway half of the bridge. But before offering the slabs to the city as part of the solution of the bridge problem, that company subjected a typical slab to a period of conclusive testing by placing it over a masonry pit directly in a route much used by heavy motor traffic. As a result of that experience, the deck slabs for the bridge were planned so as to meet the maximum traffic demands likely to be made on that river crossing. The aluminum-alloy members were as strong as similar members of silicon steel.

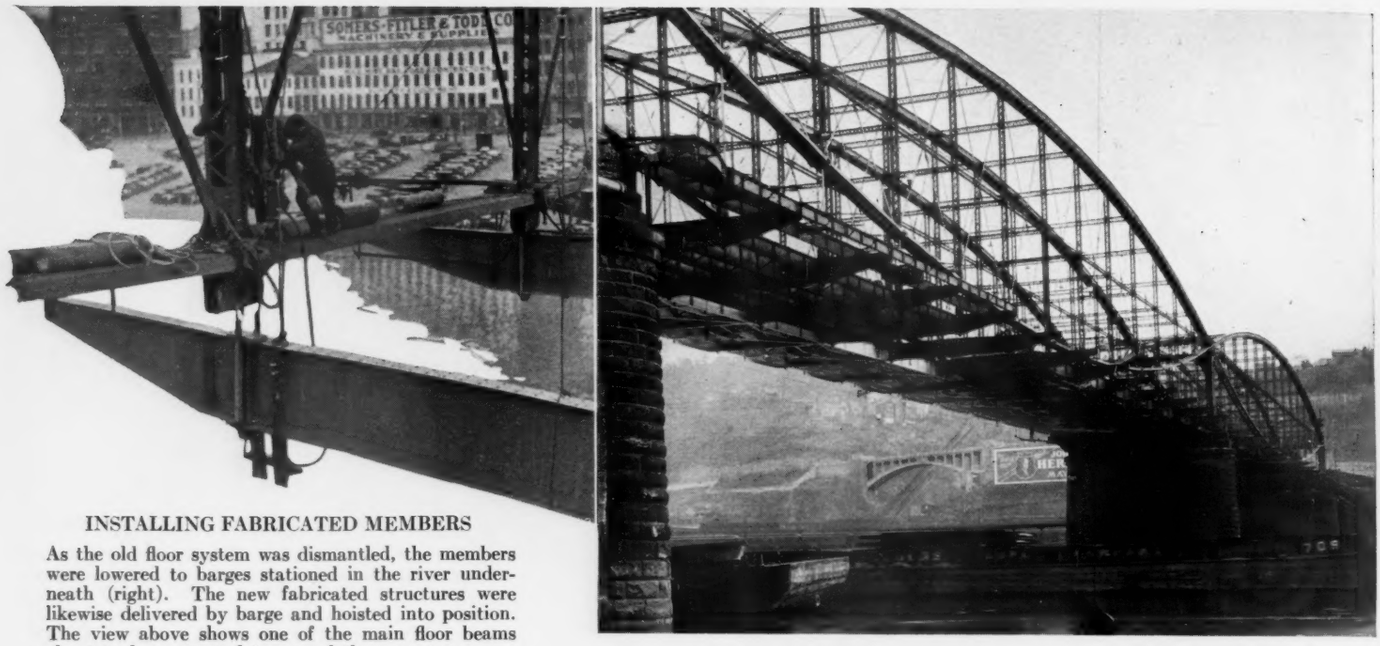
Shortly before the Department of Public Works was ready to ask for bids for the removal of the old floor and the construction of the new one, the Aluminum Company of America was able to offer another and even stronger metal, having brought its production up to a commercial scale. This aluminum alloy, known by the symbol "27 ST", is somewhat superior to "17 ST" in its physical characteristics, and, besides, is more resistant to the corrosive action of the atmosphere. Furthermore, the newer material is especially adaptable to the requirements of structural work such as the floor system typified. Aluminum alloy "27 ST" was the climax of years of research; and the several aluminum alloys that have been used on the Smithfield Street Bridge—the characteristics of which are given in an accompanying table—indicate how the metallurgist has evolved materials of differing physical properties suitable for the several services to which they are put.

To make clearer just what the substitution of the new material represents, it is only necessary to say that the aluminum-alloy shapes and plates weigh but 35 per cent of corresponding parts of identical dimensions made of steel, and this without any sacrifice in strength.

The contractor, Walter S. Rae of Pittsburgh, assumed the twofold obligation of dismantling the old floor of the bridge and of providing a new structure in accordance with the plans and specifications prepared by the Department of Public Works. A subcontract was awarded the Fort Pitt Bridge Works, of Canonsburg, Pa., for the fabrication of the various mem-

CHARACTERISTICS OF ALUMINUM ALLOYS USED ON SMITHFIELD STREET BRIDGE

Alloy	4 SH	53 ST	27 ST	17 ST
Ultimate strength	42,000	36,000	60,000	58,000
Yield point	38,000	30,000	50,000	35,000
Elongation, in 2 inches	3	12	12	20
Brinell hardness	80	80	118	100
Where used	Tubing for handrail	Rolled shapes for handrail	All floor members	Basis of design



INSTALLING FABRICATED MEMBERS

As the old floor system was dismantled, the members were lowered to barges stationed in the river underneath (right). The new fabricated structures were likewise delivered by barge and hoisted into position. The view above shows one of the main floor beams about to be connected to one of the span trusses.

bers of the aluminum-alloy floor system. We can get a fuller understanding of the job in its entirety if we start with the fabricating shop and then follow it through to its completion. While equipped for the production of steel structural parts, the facilities installed in the plant were just as successfully used in dealing with aluminum-alloy plates, angles, channels, etc. Punching, shearing, bending, drilling, were done with the usual tools provided for those purposes, and so were reaming, milling, chipping, and riveting. Where channels needed coping, or where the ends of angles had to be trimmed, that work was done in the shop with a band saw of the type generally employed for the cutting of hardwoods; and what coping was required in the field was done with a carpenter's hand saw, or the excess metal was nicked along the desired line and broken off with a few hammer blows.

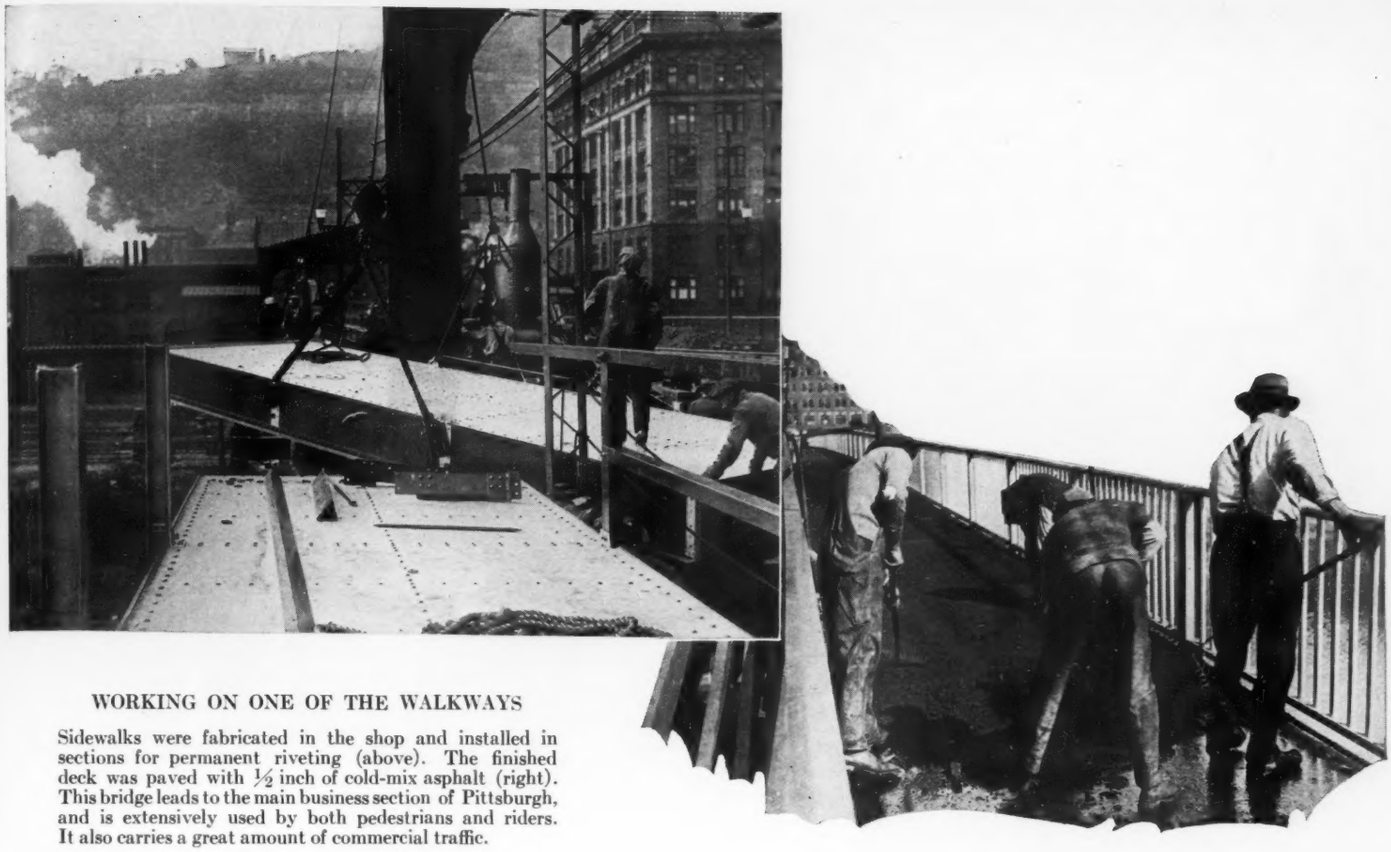
Because of the higher cost of aluminum-alloy plates and shapes, compared with the cost of similar parts of steel, greater care was exercised in layout work and in other shop operations to keep losses resulting from shop errors as low as practicable. This entailed more deliberation, but the extra time spent in this manner was largely offset by the greater general celerity in handling structural units either in moving them from point to point or in putting them through different mechanical operations. Parts that would ordinarily require the services of a power-driven hoist could be lifted and carried with ease by one or two men. Just by way of a single example, flange angles of 5x3½x$\frac{7}{16}$ inches, 27 feet long, and weighing 115 pounds, were moved easily by hand, whereas a similar shape and length of steel would have weighed 324 pounds. In the fabricating shop, the different structural members were assembled with either $\frac{5}{8}$-inch or $\frac{3}{4}$-inch buttonhead steel rivets that were driven hot; and for that purpose 70-ton squeeze riveters and pneumatic hammers were employed.

Neither the fabricator nor the erector was permitted to use rivet busters to remove defective rivets. That work was done by drilling through the head of such a rivet a hole nearly as large as its shank, and then backing out what was left of the rivet after the perforated head had been knocked off with a cape chisel. How well the riveting could be done was evidenced by the driving of $\frac{3}{4}$-inch steel rivets in track stringers for the railway floor of the bridge. Out of 18,000 driven for that purpose, only twelve were defective and had to be removed. That performance showed that the aluminum alloy, in itself, did not hamper riveting. On the other hand, neither in the shop nor on the bridge was welding or burning permitted because the aluminum alloy is a heat-treated metal and cannot be exposed to such treatment without impairment. Nevertheless, the rivets could be driven at a bright-red heat without damaging the aluminum, and, furthermore, many could be driven at a normal rate within a comparatively small area without hurting the aluminum alloy by overheating. This was demonstrated by driving quickly twenty $\frac{3}{4}$-inch rivets within an area of 9x20 inches. The temperature, which was read with a 2-point pyrometer, did not rise above 360°F., which is well below the critical temperature of the metal. All told, approximately 330 tons of aluminum shapes and plates were fabricated and worked into the floor system of the Smithfield Street Bridge; and this material was made ready for use in the shop in the brief period of parts of but two months.

Under the terms of the contract, the old bridge floor had to be dismembered and removed and the new aluminum-alloy floor put in place and made ready for traffic within a total period of only 24 days. Besides, during dismantling and renovating the bridge was to remain open for street-car service and for pedestrians. This meant, of course, that one-half had to be available for use while the other was undergoing remodeling. As soon as vehicular traffic was excluded from the highway side of the bridge, the street-car tracks were temporarily shifted to that side, and the contractor at once began the removal of the deck on the abandoned half and the reconstruction of the floor system with aluminum-alloy main beams, intermediate beams, and stringers. So carefully coördinated was the work of the erectors, the fitters, and the riveters that that half of the bridge was built, new ties and rails laid, and other essential operations completed within the astonishingly brief time of nine days. The street cars were then returned to their own side of the bridge, and the contractor promptly started the dismantling of the highway half of the floor system. This part of the bridge was constructed in 1882, and its demolition was more difficult because the contractor had to take up the thick timber decking and to proceed cautiously in removing the old wrought-iron main beams.

The street-car side of the bridge floor was tied to the original floor beams of the highway half by the riveted splices previously mentioned and that were a few inches from the upstream side of the central trusses—that is, on the street-car half. Therefore, before any of the main beams of the highway floor could be detached, the corresponding beam had to be held up at its free end until the new floor beam on the highway side had been put in place and spliced to its companion beam on the opposite side. A framework, functioning as a king-post truss, with a sufficient longitudinal span provided the necessary temporary support, and was shifted from beam to beam as the work advanced.

For certain structural reasons that it is not necessary to go into here, the dismembering of the old floor and the construction of the new one had to proceed from the center of each span toward the ends. This made it impossible for trucks to be used in carrying off the old metal and in bringing the new; but the



WORKING ON ONE OF THE WALKWAYS

Sidewalks were fabricated in the shop and installed in sections for permanent riveting (above). The finished deck was paved with ½ inch of cold-mix asphalt (right). This bridge leads to the main business section of Pittsburgh, and is extensively used by both pedestrians and riders. It also carries a great amount of commercial traffic.

difficulty was overcome by employing barges that were spotted directly beneath the bridge wherever required. Thus the detached sections were lowered and taken away while the new structural parts and materials were delivered and hoisted into their prescribed positions.

As some of our photographs show, the sidewalks consist of shop-fabricated sections, while the highway deck is formed of a series of ribbed slabs each 27 feet 7⅝ inches long and 11 feet wide. Two such slabs, placed side by side, cover an entire panel of the floor. Distributing channels, riveted to the undersides of these slabs, are the means by which concentrated wheel loads are distributed so that the stresses can be absorbed by neighboring parts of the slab structure. Several of the illustrations show the highway deck during different stages of construction; and one of them gives a good idea of how the deck appeared just before it was surfaced with its single course of cold-mix asphalt 1½ inches thick. That pavement will take the wear and tear of vehicular traffic, and is the present-day substitute for the former heavy, inflammable timber deck.

The asphaltic pavement is anchored to the deck plating by the rivet heads and by the patterned surface impressed on the upper side of the plating at the time it was rolled at the mill. There is a pavement of the same kind but ½ inch thick on each of the sidewalks where the decking used to be of 2-inch planks. Except for a few relatively inconsequential details, the highway half of the bridge and the contiguous sidewalk were finished and ready for traffic at the end of the prescribed 24 days. The railing on one side of the structure was erected one night in the course of one hour and eight minutes by a gang of only ten men. It consists of 72 fabricated panels each 9 feet long; and the workers had to carry the panels from a storage point at one end of the bridge. This is another example of what the aluminum alloys make possible because of their light weight.

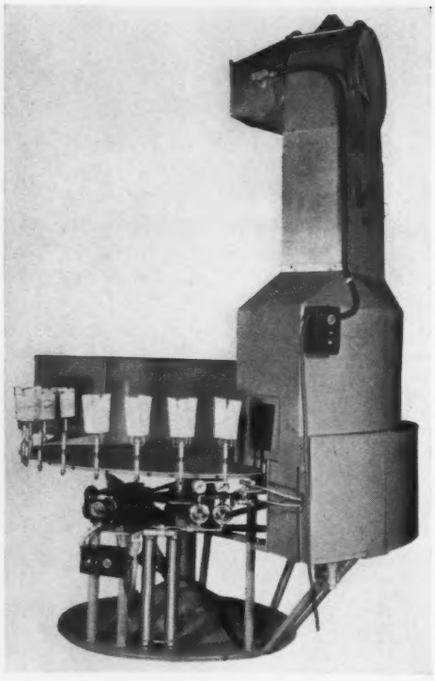
It should be understood, of course, that the entire floor was assembled by riveting; and air to operate the riveting hammers, reamers, and chippers was supplied by four portable compressors, two at each end of the bridge, having a combined capacity of 880 cfm. A receiver, of 100 cubic feet capacity, was installed at the end of each air line near the center pier. All structural parts were painted by hand in the fabricating shop. This was done after the metal had been cleaned with a dilute acid solution and then washed off with water. The paint was an iron-oxide-zinc chromate pigment that was mixed in a vehicle of bakelite varnish.

In its previous state, the floor system of the Smithfield Street Bridge weighed 1,548.98 tons: as it stands today in its remodeled form it weighs 797.55 tons—a saving in dead weight of 751.43 tons. The trusses, therefore, have a correspondingly lighter dead load to carry and are thus enabled to support a considerably heavier live load represented by street cars, automotive vehicles, and pedestrians. Certain restrictions upon the street cars, previously enforced, have been lifted, and the lines using the crossing are now free to handle more passengers and can, in consequence, deal properly with peak-load demands. Likewise, the bridge can safely accommodate a larger volume of vehicular traffic. Where the maximum truck load was once limited to 13 tons on four wheels, the limit is now 20 tons on the same number of wheels. In other words, the bridge, in the opinion of competent experts, will be able to meet the increasing demands of traffic for a quarter of a century to come, and all because of what aluminum alloys have made not only practicable but safe at the same time.

The contract price for the renovation was $276,436; and the ultimate outlay on the 10-year bond issue will bring the final cost to the city up to $370,125—that sum virtually giving Pittsburgh the equivalent of a new bridge. On the other hand, an entirely new steel structure of the same capacity, covered by a 25-year bond issue, would have involved, at present construction costs, an expenditure of $1,935,000. The substitution of an aluminum floor system has saved the pockets of Pittsburgh's taxpayers the very considerable levy of $1,564,875.

What has been done in the case of the Smithfield Street Bridge may be done to rehabilitate others; and, furthermore, the example set in the present instance undoubtedly will influence engineers who are now engaged or who are likely to be engaged in the designing of new bridges. As a matter of fact, in view of the results obtained, it is reasonable to assume that the research and the enterprise of the Aluminum Company of America will have far-reaching effects on various departments of engineering.

Air-Spray Machines for Hot Fluids



COATING MACHINES

Paraffin, wax, asphalt, and the like can be applied in a molten state to sheets and to shapes of various materials by these air-spray machines which operate automatically except for loading. The unit above is designed for flat work, while the one on the left handles containers of different forms and sizes. It is shown wax-coating receptacles of the kind widely used in carrying home ice cream.

PAPER-BOARD containers of all kinds are being widely used today both for sanitary reasons and for convenience in dispensing beverages and for carrying foodstuffs of a fluid or semifluid nature. These cups, cans, pails, or the like, are coated with wax so that they will remain proof against leakage for reasonable periods. The application of this finishing material, to keep pace with the rest of the manufacturing processes, is now generally done mechanically, and in this work compressed air plays an important part.

The Paasche Airbrush Company has developed a so-called wax aircoating machine that operates on the principle of the paint-spray outfit. Except for the loading, which must be done by hand, it functions automatically and can be adjusted to take containers of a variety of shapes and sizes. These are held by revolving holders mounted on a revolving table that is driven by a variable-speed motor. By simply regulating the rate of speed at which the cups, for example, are carried through the spray cabinet, they can be given either a heavy or a light film; and this film, depending upon the service to which they are to be put, can be applied either on the inside or on the outside, or simultaneously both inside and outside.

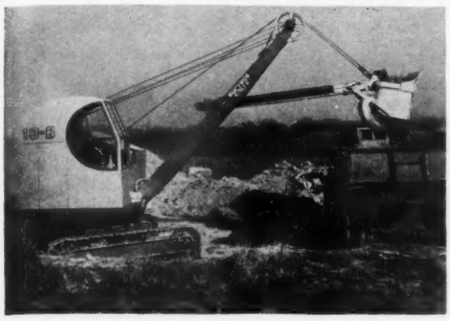
As each container reaches the coating station, the air guns are cut in automatically by on-and-off control and, by means of an oscillating device, are made to travel with the table as long as spraying continues. The molten paraffin or other suitable substance is fed to the guns by compressed air which varies in pressure according to the consistency of the fluid mass. The temperature of the air as well as of the wax is under thermostatic control; and the cabinet is arranged to collect the off-spray and to drain it back into the feed tank.

All the while coating is in progress the containers revolve, thus assuring complete coverage and a film of uniform thickness except at the corners or the seams where the deposit is heavier. As soon as the pieces emerge from the hot compartment the wax chills and they are mechanically cast from their holders. Anywhere from 2,000 to 5,500 containers can be treated in an hour, depending upon the speed with which the loading can be done.

The pressure feed tanks are separate units and range in capacity from 6 to 70 gallons and more, if desired. They are built to withstand a maximum pressure of 100 pounds per square inch and are provided with clamp-tight covers, agitators, and the necessary air regulators and gauges. Before air is admitted to a tank it is passed through a separator to free it of all moisture, oil, and foreign matter. For the application of paraffin, asphalt, etc., an electrically heated feed tank with thermostatic control permits raising the temperature of the contents up to 850° F., if necessary.

A machine of the same general type for flat work is also available. It is operated by two men, one at the feeding and the other at the discharge end of a continuous conveyor that carries the sheets first through a preheater and then through the spray cabinet. In the preheater they are raised to a temperature that will assure proper fusing of the coating material. The air guns are constructed to withstand intense heat, and can be regulated with ease to produce a fan spray up to 60 inches wide and as light or as heavy as may be desired. A specially designed fume housing and ventilating unit makes for healthful working conditions and collects the off-spray for re-use. Output also depends upon loading, as the guns, compressed air, heat, feed, etc., are under such accurate control as to insure uniform results at any conveyor speed.

BUCYRUS-ERIE ANNOUNCES NEW CONVERTIBLE EXCAVATOR



BUCYRUS-ERIE Company, of South Milwaukee, Wis., has announced a new ⅜-yard, full-revolving excavator which, by using suitable equipment, can be quickly converted into a shovel, dragline, crane, clamshell, drag shovel, skimmer scoop, back filler, or pile driver. The machine is designated the 10-B. As a shovel, with standard boom at 45°, it has a maximum cutting radius of 20¼ feet and a clear dumping height of 12½ feet. The crane rating at 10-foot radius is 7,000 pounds. As a clamshell or dragline, it handles a ⅜-yard bucket on a 28-foot boom.

Special features of the 10-B are its light weight and great mobility. Depending upon the equipment used, it ranges from 7½ to 8 tons in weight, which is low enough to permit it to be moved over highways. It will travel at speeds up to 4½ miles per hour, will make right-angle turns readily, and will climb grades of 30 per cent and more. Full details may be had by writing the manufacturer.

SAND BLAST PUT TO NOVEL USE BY MINING ENGINEER

THE sand blast has many applications in the arts and industries, but it is doubtful if it has ever been put to a more novel use than that employed recently in Canada by a mining engineer. In this instance, as reported by *The Northern Miner*, it was the means of frustrating what may have been an attempt by unscrupulous mining promoters to misrepresent the value of their property for the presumed purpose of selling it.

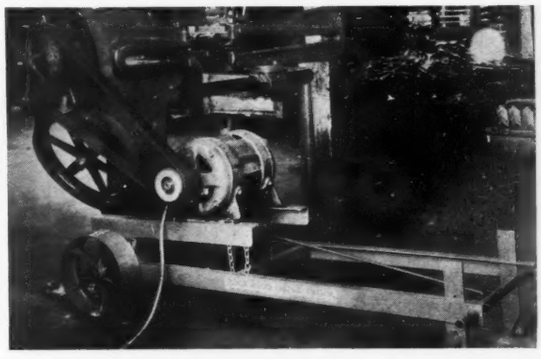
The property in question had long been the subject of legends which ascribed to it great richness. Reports had emanated from British Columbia from time to time to the effect that the 450 acres comprising the claim constituted, veritably, a "mountain of gold." Over a period of several years various investigators had inspected the ground and taken hundreds of samples which seemed to indicate that there were vast quantities of quartzite which would average well over $3 to the ton in gold. The prospectus issued by the claim holders estimated that there were 1,384,000 tons of this rock which could be recovered and put through the stamp mills.

A few months ago a Toronto company became interested as prospective purchasers of the "mountain of gold" and took steps to examine the property thoroughly. James G. McGregor, a mining engineer of repute, was engaged to make an investigation and to submit a report. Mr. McGregor took 203 samples of surface material which were assayed in the field by a man of his own choosing and whose integrity was beyond question. The returns showed an average value of $3.04 a ton in gold. As a check on this finding, Mr. McGregor submitted 228 samples to an independent assayer in Ottawa, who likewise found that the quartzite carried considerable values.

As a final precaution, however, Mr. McGregor sand blasted various areas of the rock to remove all loose and adhering surficial material. From these scoured patches he then took samples by chipping off pieces of rock. The samples thus collected totaled 100 pounds. These he took with him under lock and key and guarded carefully until he could have them assayed. This time the assayer's report revealed that the rock was worthless so far as any gold content was concerned. While he made no charges of attempted fraud, Mr. McGregor stated in his report that he was "at a loss to understand how so many other investigators had reported the presence of consistently high values in areas where he could obtain only traces at the best. These facts," he wrote, "admit of no logical solution, and the situation can only be termed highly unsatisfactory."

PORTABLE MOTOR-DRIVE TRUCK REDUCES PLANT DELAYS

THERE are times in many shops when a machine stands idle because its driving motor needs repairs or when a group of machines that receive power from one source must be operated in order to use any one of them. For service in such cases a portable motor-drive truck has been developed by the Rockwood Manufacturing Company of Indianapolis, Ind. As illustrated, it consists of a standard Rockwood drive mounted on a structural-steel truck. It will accommodate practically any standard make of motor or gas engine weighing up to 500 pounds. It can be handled by one man, and can be secured in position and connected for service in a few minutes. This unit was originally applied to the agricultural field, and its success there led to its adoption in industrial plants. Details and prices may be secured by writing the manufacturer.

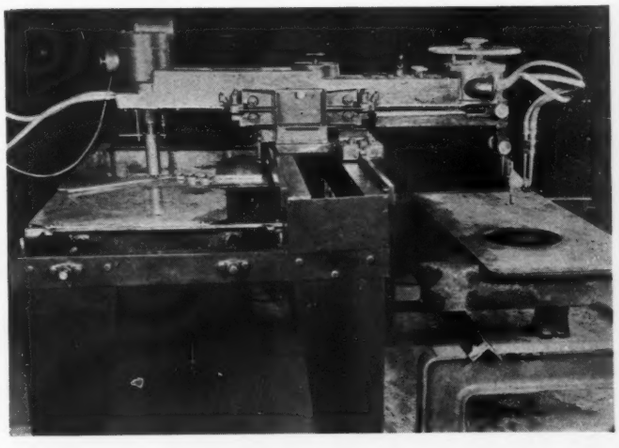


PRECISION CUTTING MACHINE FOR SMALL-SCALE WORK

SHOPS that are called upon to do much precision cutting of small-scale shapes should be interested in the "Pantosec", a remarkably flexible stationary instrument that is designed to make that work less of a task and to speed it up considerably. It is manufactured by The Linde Air Products Company, and is especially suitable for turning out dies, cams, and other parts that must be smooth and accurate.

The "Pantosec" has a cutting range of 44 inches longitudinally and of 20 inches laterally, and is said to cut straight lines, angles, circles, and intricate shapes, and to do beveling with equal facility. It can be operated with a minimum of attention from either the templet or the blowpipe end, and can be guided by hand or mechanical means. The instrument is adjusted to the work, and this makes it possible to line up the blowpipe without shifting the work. Angles can be cut without the use of patterns, as the cutting head can be locked for travel in any direction; and the dividing head enables the operator to set stops on work that requires cutting in several directions. Through the medium of an extension, mounted so as to be always steady, it is unnecessary to return to the templet end of the instrument to start profile cutting after the entry cut has been made.

The machine consists of a carriage, on 3-point supports, within which the gas piping is inclosed. All drives are protected by dirt-proof casings; and the switches and controls are plainly marked and easily accessible. It occupies but 72x83 inches of floor space.



This and That

Stone Mountain Again

Work is to be resumed on the heroic memorial to the Confederacy on Stone Mountain, near Atlanta, Ga. The Memorial and Monumental Commission of Georgia will direct the work, and has retained Gutzon Borglum, the original sculptor, to prepare designs and to supervise the carving. A new site will be selected, and the figures will be done on a scale almost three times as large as those which were previously started. It is anticipated that the work will be done chiefly with compressed-air tools, as that method was used successfully before and is now being effectively employed at Mount Rushmore, S. D., where a national memorial is being carved under the direction of Mr. Borglum.

Drinking in the Deep

Last month the newspapers published a story from London featuring an unusual exploit by a diver named Tom. Tom was salvaging cargo from a sunken ship 60 feet underwater, but he suddenly ceased to send up retrieved goods and failed to respond to tugs upon his lifeline. Fears were felt for his safety, but after a time he came to the surface. He was feeling fine—in fact, he was mildly inebriated. As he had gone down sober, it was obvious that he had somehow managed to have a few drinks in Davy Jones's locker. Yet this didn't seem possible.

Tom explained that while at work he suddenly realized that his hands were out of water. He was in the hold, on top of some cargo, and his head was near the top of an angular space between a side of the listed ship and a deck floor. Air from the hold, supplemented by that escaping from his helmet, had formed a great bubble there. Tom had just run across some cases of whisky, so, feeling in the mood for a drink, he secured a bottle, resumed his station, moored his lifeline to prevent interruption, unscrewed his helmet, and proceeded to enjoy himself. He sat in water up to his chin. Had the hull listed, had he slipped, or had any one of a dozen other things happened, drowning would have been his lot. But he took a chance, and lived to take others.

This story, although vouched for by Sir Robert Davis, authority on deep-sea diving, was questioned in this country. However, various experts, among them Com. Edward Ellsberg, accepted it as plausible and recalled instances in their experiences where they had observed similar trapped air pockets. In any event, the tale makes a good companion for the one printed in these columns in January, 1929. Briefly, it described a dinner party given London officials in a caisson under 30 pounds air pressure to celebrate the completion of the Blackwall Tunnel underneath the Thames River. The champagne failed to effervesce and it tasted flat, but the diners drank considerable of it because they were thirsty. Later, when they began to decompress in locking out, the gas bubbles in the liquor they had swallowed began to expand and they were a miserable group. The pressure was restored, a stomach pump brought into play, and all was well.

Construction Job Language

Construction jobs have a way of developing a language all their own. It is picturesque, but somewhat unintelligible to the layman that wanders on to the scene. A few months ago the writer was being shown over a large foundation undertaking in New York City by the superintendent. A foreman interrupted to report an unexpected situation which called for handling some heavy steel and asked for instructions. The superintendent meditatively rubbed his chin a moment and then suggested that "Mickey Mouse" be brought over to do the job. With an "O. K." the foreman strode off. There was no doubt that he understood, although to the visitor the superintendent's remarks had been about as clear as mud. Discreet questioning later elicited the information that "Mickey Mouse" was a huge crane which was, at the time, standing idle in the contractor's yard in Long Island City.

Boulder Dam Lingo

Jobs of long duration, such as the building of Boulder Dam, afford time for a profusion of construction lingo to grow. Words are coined to designate almost all routine operations and items of equipment. Many of the terms are so apt that they quickly come into general usage and even appear in technical accounts of the work. For example, when Bernard "Woody" Williams, young assistant superintendent for Six Companies Inc., saw the size of the first of the drill carriages which he had designed for drilling the benches in the 56-foot diversion tunnels, he immediately dubbed it "jumbo." The name was appropriate, and it stuck.

Many of the terms originate for the sake of brevity. Of this type is "cowdozer," which is a tractor equipped with a blade on the back which is let down next to a tunnel wall or cliff to pull muck away from the base. Its evolution is logical, inasmuch as a similar contrivance, having the blade on the front and designed for pushing muck had been previously named a "bulldozer." Other words savor of the burlesque, such as "easy-dough" for boss.

Some of the terms are not indigenous to Boulder Dam, but were carried there by workmen from other construction jobs. Similarly, some of those that sprang into being in Black Canyon will continue to live on future undertakings. A few of them will perhaps eventually attain the status of good English and will find a place in the dictionary, just as "muck," "mucker," "catwalk," and others have.

Instead of saying that it is time for him to go on shift, a workman at the dam announces that he has to go "build it." An ordinary shovel is to him a "banjo." A long-handled shovel is a "crutch," probably because it is convenient to lean upon. The canyon is the "hole," and the excavated area where the dam is now being reared was the "glory hole." An electrician is a "juicer," and a carpenter a "wood-butcher."

A "goldbrick"—a survival of A. E. F. days—is a fellow who gets by without doing much work, and his job is a "gravy-train." When a worker takes a short rest on company time, he speaks of it as "taking five," or "getting a spot."

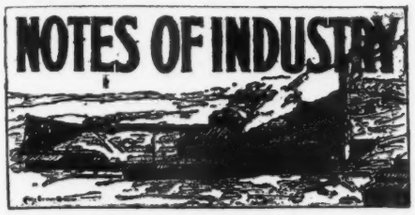
Any sort of improvised or makeshift equipment is called a "Joe McGee." The Government 150-ton aerial cableway—the largest of its kind—is known as "King Kong." The men in the canyon who transmit signals to the operators of the cableways high above them are "signal punks."

An alternate of "easy-dough" for boss is "gaffer," and a "stooge" is a worker who caters to or "apple-polishes" his "gaffer." The portion of the dining hall in which the officials and bosses eat is the "blue room."

A truck driver is known, inelegantly, as a "double-ugly." Mixed concrete is called "mud." Light Ford trucks are termed "candy wagons," and heavier trucks "cornbinders." The double-deck motor transports, on which 150 men ride to and from their work at a time, are "Big Berthas." Girl sight-seers are known as "twirps," or "twidgetts."

Filming Stomach's Interior

The latest achievement in the realm of photography is the development of a tiny camera that will take interior pictures of the human stomach. A Vienna product, it comprises a lens, a film roll, and a miniature flash bulb, all housed in a metallic cylinder 2 inches long and ½ inch in diameter. It operates at an exposure of 120th of a second, and takes sixteen pictures at a time. It is swallowed by the patient, and a connecting rubber tube serves both as a means of withdrawing it from the stomach and of setting off the flash bulb through the agency of a plunger. The camera was used recently at Hahnemann Hospital, Philadelphia, Pa., to assist doctors in diagnosing a perplexing stomach ailment. The patient's stomach was distended by pumping air into it to keep the tissues away from the lens. The entire procedure consumed less than two minutes. Physicians believe the diminutive camera will make it possible to detect stomach disorders before they have progressed to a stage that can be recorded by the X-ray.



Hand-shaved poles, reports the American Wood Preservers Association, are a thing of the past in Germany, where a machine has been introduced to do this work. Poles so finished are said to be exceptionally smooth.

Helium deposits that are claimed to exceed in extent those existing in the United States have been discovered in six different districts in Russia. The former has been the only country in the world to produce that noninflammable gas in sufficient quantities for use in airships.

What is said to be the first deep mine in the United States to be air conditioned is operated at Butte, Mont., by the Anaconda Copper Mining Company. The air is kept at a uniform temperature of approximately 75°F. even in workings where it would normally be around 120°.

Gas masks of the canister type for use in gaseous atmospheres have been considerably improved upon by one manufacturer who has provided the face piece with a device that permits men so equipped to talk together freely, something that is not possible with the ordinary breathing apparatus of this kind.

Bags lined with cellophane make it practicable to store lime for a year and more without absorbing moisture, says the Rockland & Rockport Lime Corporation of Rockland, Me. The bag was developed by that company to prevent the breakage so frequently caused through heating and swelling of the contained lime.

The Incandescent Lamp Department of the General Electric Company has announced a new lamp that provides three degrees of illumination. The single bulb contains two filaments which may be burned individually or together. At present it comes in two sizes: in combinations of 150- and 200-watt filaments and of 200- and 300-watt filaments.

DuPont thermoplastic cements will bind together anything, it is reported—cellophane and metal-foil; delicate fabrics and heavy backings; and paper, wood, glass, cork, metal, and other materials may be permanently affixed to one another by these highly adhesive substances. Depending upon the scale on which they are used, they are applied by machine, by brush, or by air spray.

Water paint of a new kind and of a variety of colors for plaster, cement, and concrete is being offered by the Master Builders Company of Cleveland, Ohio, as a product of its research laboratories. It may be applied to damp or dry masonry surfaces either by brush or by air spray, and is said to be waterproof and, because it hardens quickly, to be unaffected by moisture, efflorescence, etc.,

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Puget Sound on the Pacific Coast has recently been the scene of demonstrations with a new diving bell for salvage work designed by Gene Romano, a mechanical engineer. The pear-shaped steel globe is equipped with articulated arms having clawlike fingers, with flood lights, telephone, etc., and carries tanks of compressed air and oxygen. Capt. C. B. Mayo, of the United States Navy, is said to have descended in it to a depth of as much as 400 feet.

A line of coatings and dressings for dies and molds for nonferrous metals has been introduced by the St. John X-Ray Service, Inc., under the trade name of "Bonis." These materials are said to act as an insulator as well as a lubricator, and to give the castings a smooth appearance and a good finish. They are applied to the surfaces of the hot dies or molds with air under pressure, thus filling the pores and fine cracks. One application lasts, so it is claimed, for 300 shots in a die-casting machine.

Gypsum planks that can be used instead of wooden ones are being produced under the trade name of "Gypsteel". The boards are solid, and are 2 inches thick, 15 inches wide, and 10 feet long. They can be handled the same as wood—cut, sawed, nailed, bored, etc.; are also tongued and grooved for joining; and the edges and ends are reinforced with metal. The material has the advantage of being fireproof and of possessing insulating properties. It can be surfaced, if desired, with cement, linoleum, or mastic.

In the construction of the new Grönvollfass Dam, in Norway, the cement used consisted of a mixture of 30 to 40 per cent first-grade, ground portland-cement clinker and of 60 to 70 per cent ground blast-furnace slag obtained from Germany. The resulting slag-cement had a specific gravity of 2.45 and a moisture-absorption power after hardening of 2.2 per cent. Leaching tests in the laboratory revealed the material to be three times more resistant to water than portland cement and that it developed but half the amount of heat in setting as do ordinary cements. The slag-cement is the outcome of investigations undertaken after some of the older dams in Norway and elsewhere showed that they had become pervious to water.

Successful tests in Switzerland of a new type of safety railroad brake are reported by the United States commercial attaché stationed at Berne. The brake is designed to function automatically, to stop a train, should the engineer fail to do so at a given signal. The mechanism is not complicated, and consists of a small wheel, on the locomotive, and of an adjustable iron band or rail running parallel with and close to the track. The instant the signal is closed, the supplemental rail is automatically lifted and brought in contact with the wheel, causing it to turn and, through a special device, to set the regular brake. One of the heaviest of the Swiss electric locomotives was used for the tests; and the system is said to have functioned without shock with the train running at speeds varying from 30 to 70 miles an hour.

A FRIEND IN NEED

That is what this locomotive proved to be in an emergency at the plant of the Fauerbach Brewing Company of Madison, Wis. The brewery was recently forced to overhaul its two 150-hp. boilers, but found that it would be impossible to shut down one and use the other for the time being because one alone could not supply sufficient power to keep the plant operating at capacity. Here is where the locomotive comes in: it was rented from the Chicago & North Western Railway, and for eight days did a fine job of pinch-hitting for each boiler in turn while it was out of commission.

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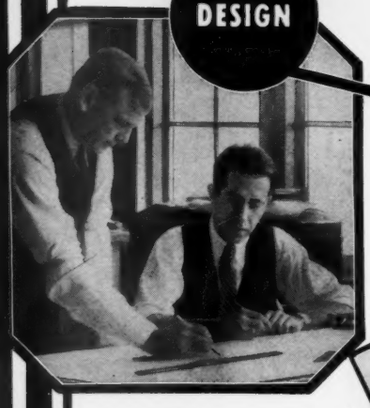
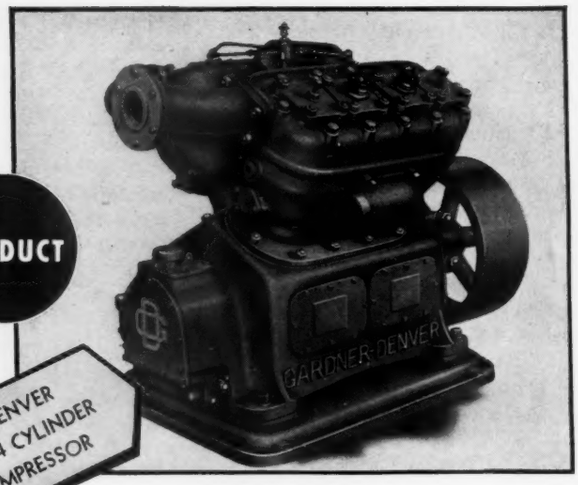


PRODUCT



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